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THE ENGINEER'S EXAMINATION MADE EASY

THE

ENGINEER'S

EXAMINATION

MADE EASY

BY

ROBERT THOMSON.

"Read not to contradict and confute, nor to believe and take for granted, nor to find talk and discourse, but weigh and consider, or with a desire to learn which may be obtained by diligence and attention."—*Lord Bacon.*

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PREFACE.

———oo———

THE subjects of the following pages were compiled by the Author for the assistance of three of his sons, who are following the same calling as himself, viz., the Engineering business, and to be in manuscript only. At the request of a large number of individuals for copies of this work, it is now put before the public.

The object aimed at is plainness and simplicity, with as little labour as possible. To be plain, it often follows that there are repetitions, this is considered necessary under certain circumstances. A large number of valuable works are before the public; but a large amount of the information these contain, is lost to the Practical Engineer in consequence of their Problems being solved by Algebra. The Author believes he is able to judge of the truth of this statement, having worked for more than twenty years on shore, in the erecting shops of the manufacturers of the Steam Engine in London and Glasgow—besides being more than twelve years at sea, as a sea going Engineer—

and draws the conclusion from experience that the useful knowledge of Algebra is unknown to ninety-nine out of every hundred of his class.

The Merchant Shipping Acts Amendment Act has increased the demand for some work plain and simple, with instructions for the guidance of those that may not have the advantage of a Tutor. An Engineer before he can hold the situation of 2nd Engineer at sea, (if the Ship is propelled by more than 100 nominal horse power,) has to be examined by the Board of Trade as to competency. This examination is so varied and intricate, that it requires him not only to know how to make the Steam Engine in its various shapes and forms with the strength of material, &c.; but he is also questioned as to what he would do under certain circumstances or difficulties in connection with Machinery, while perhaps the idea has not occured to him before, and if unable to give a satisfactory answer, his certificaté may be withheld and loses the half of the fee paid for his examination. He also requires to know something about Chemistry.

To help him for this examination, the Author has written this work, beginning with simple proportion, proceeding from one rule in Arithmetic to another—often giving two examples of the same question—showing how much easier it is to work by cancelling or abreviation, than by the multiplying and dividing by the same figures. The Author

has also devoted a large part of this work for the Viva Voce examination, and hopes that the information it contains will assist the Engineer in passing a creditable examination.

The Author acknowledges he is indebted for his information on the bursting pressure of Cylindrical Boilers, &c., from a very valuable work titled "Information for Engineers," imboding several experiments made by William Fairbarn, Esq., of Manchester; also quotations from the following works:—Hutton's Mathematics, Templeton Brunton on Mechanics, Murray on the Marine Engine, Bourne's Catechism, Jamieson's Mechanical Dictionary, Mechanics Magazine, &c.

ACT OF PARLIAMENT.

Certificates for Engineers (PART III. *of Merchant Shipping Act*, 1854.)

Steam Ships to carry Certificated Engineers.

On and after the first day of *June*, one thousand eight hundred and sixty three, every Steam Ship which is required by the principal Act to have a Master possessing a Certificate from the Board of Trade, shall also have an Engineer or Engineers possessing a Certificate or Certificates from the Board of Trade, as follows, that is to say:—

(1.) Engineers Certificates shall be of two grades, namely, "First-class Engineers Certificates," and "Second-class Engineers Certificates."

(2.) Every Foreign-going Steam Ship of one hundred nominal horse-power or upwards shall have as its First and Second Engineers two Certificated Engineers, the first possessing a "First-class Engineer's Certificate," and the second possessing a "Second-class Engineer's Certificate," or a Certificate of the higher grade.

(3) Every Foreign-going Steam Ship of less than one hundred nominal horse-power shall have as its only or First Engineer an Engineer possessing a "Second-class Engineer's Certificate," or a Certificate of the higher grade.

(4) Every Sea-going Home Trade Passenger Steam Ship shall have as its only or First Engineer an Engineer possessing a "Second-class Engineer's Certificate," or a Certificate of the higher grade.

(5) Every person who, having been engaged to serve in any of the above capacities in any Steam Ship as aforesaid, goes to sea in that capacity without being at the time entitled to and possessed of such Certificate as is required by this section, and every person who employs any person in any of the above capacities in such ship without ascertaining that he is at the time entitled to and possessed of such Certificate as is required by this section, shall for each such offence incur a penalty not exceeding Fifty Pounds.

Examinations for Engineer's Certificates of Competency.

The Board of Trade shall from time to time cause Examinations to be held of Persons who may be desirous of obtaining Certificates of Competency as Engineers: For the purpose of such Examination the Board of Trade shall from time to time appoint and remove Examiners, and to award the Remuneration to be paid to them; lay down Rules as to the Qualification of Applicants, and as to the times and places of Examination; and generally do all such Acts as it thinks expedient in order to carry into effect the Examination of such Engineers as aforesaid.

Fees to be paid by Applicants for Examination.

All Applicants for Examination shall pay such Fees, not exceeding the Sums specified in the Table marked (B) in the Schedule hereto, as the Board of Trade directs;

and such Fees shall be paid to such Person as the said Board appoints for that purpose, and shall be carried to the Account of the Mercantile Marine Fund.

TABLE B.

Fees to be charged on Examination of Engineers.

For a First-class Engineer's Certificate.........	£2	0	0
For a Second-class Engineer's Certificate......	1	0	0

Certificates of Competency to be granted to those who pass.

The Board of Trade shall deliver to every Applicant who is duly reported to have passed the Examination satisfactorily, and to have given satisfactory evidence of his Sobriety, Experience, and Ability, a Certificate of Competency, as First-class Engineer or as Second-class Engineer as the case may be.

Engineer's Certificates of Service to be delivered on Proof of certain Service.

Certificates of Service for Engineers, differing in form from Certificates of Competency, shall be granted as follows; that is to say,

(1) Every person who, before the first day of *April*, one thousand eight hundred and sixty-two, had served as First Engineer in any Foreign-going Steam Ship of one hundred nominal horse-power or upwards, or who has attained or attains the rank of Engineer in the service of Her Majesty or of the

East India Company, shall be entitled to a "First-class Engineer's Certificate" of service.

(2) Every Person who, before the first day of *April*, one thousand eight-hundred and sixty-two, had served as Second Engineer in any Foreign-going Steam Ship of one hundred nominal horse-power or upwards, or as First or only Engineer in any other Steam Ship, or who has attained or attains the rank of First-class Assistant Engineer in the Service of Her Majesty, shall be entitled to a "Second-class Engineer's Certificate" of Service.

Each of such Certificates of Service shall contain particulars of the name, place, and time of birth, and the length and nature of the previous service of the person to whom the same is delivered; and the Board of Trade shall deliver such Certificates of Service to the various persons so respectively entitled thereto, upon their proving themselves to have attained such rank or to have served as aforesaid, and upon their giving a full and satisfactory account of the particulars aforesaid.

Certain Provisions of Merchant Shipping Act to apply to Engineer's Certificates.

The provisions of the principal Act, with respect to the Certificates of Competency or service of Masters and Mates, contained in the 138th, 139th, 140th, 161st, and 162nd Sections of the Act, shall apply to Certificates of Competency or Service granted under this Act, in the same manner as if Certificates of Competency and Service to be granted to Engineers under this Act were specially mentioned and included in the said Sections.

Power of Board of Trade and Local Marine Board to investigate Conduct of Certificated Engineers.

The power by the 241st Section of the principal Act given to the Board of Trade, or to any Local Marine Board, of instituting investigations into the conduct of any Master or Mate whom it has reason to believe to be, from Incompetency or Misconduct, unfit to discharge his duties, shall extend to any Certificated Engineer whom the Board of Trade or any Local Marine Board has reason to believe to be from Incompetency or Misconduct unfit to discharge his duties, in the same manner as if in the said Section the words "Certificated Engineer" had been inserted after "Master" wherever "Master" occurs in such Section.

Declaration of Engineering Surveyor to contain Sttaement concerning Engineer's Certificate.

The declaration required to be given by the Engineer Surveyor under section 309 of the principal Act shall, in the case of a ship by this Act required to have a Certificated Engineer, contain, in addition to the statements in the said section mentioned, a statement that the Certificate or Certificates of the Engineer or Engineers of such ship is or are such and in such condition as is required by this Act.

Certificate to be delivered up.

Every Master or Mate or Engineer whose Certificate is or is to be suspended or cancelled in pursuance of this Act shall, upon demand of the Board, Court, or Tribunal by which the case is investigated or tried, deliver his Certificate to them, or, if it is not demanded by such Board, Court, or Tribunal, shall, upon demand, deliver it to the Board of Trade, or as it directs, and in default shall for each Offence incur a Penalty not exceeding Fifty Pounds.

BOARD OF TRADE.

OFFICIAL NOTICE.—Engineers's Certificates under the Merchant Shipping Acts, &c., Amendment Act, 1862.

1st.—After the 1st of June, 1863, no "Foreign-going Steam Ship," or "Home-trade Passenger Steam Ship," can obtain a clearance or transire, or legally proceed to sea, from any port in the United Kingdom, unless in the case of a Foreign-going Steam Ship of 100 horse-power "nominal" or upwards, the first and second Engineers, and in the case of a Foreign-going Steam Ship of less than 100 nominal horse-power, or a Home-trade Passenger Steam Ship, the first or only Engineer, as the case may be, have obtained and possess valid certificate either of competency or service, appropriate to their several stations in such Steam Ships or of a higher grade.

2nd.—The Certificates of Engineers are of two descriptions, viz., certificates of competency and certificates of service, and for each description of certificate there are two grades, viz., first-class Engineers' certificates and second-class Engineers' certificates.

Qualifications for Certificates of Competency.—Second-class Engineers.

3rd.—A candidate for a second-class Engineers' certificate must be 21 years of age.

He must have served an apprenticeship to an Engineer, or prove that for not less than three years he has been employed in some factory or workshop on the making or repairing of engines, and must also have served one year at sea in the engine-room; or he must have served at least four years at sea in the engine-room.

(2.) He must be able to give a description of boilers and the method of staying them, together with the use and management of the different valves, cocks, pipes, and connections.

He must understand the use of the barometer, thermometer, hydrometer, and salinometer.

He must understand how to correct defects from accident, decay, &c., and the means for repairing such defects.

He must state the cause, effects, and usual remedies for incrustation and corrosion.

He must be able to state how a temporary or permanent repair could be effected in case of derangement of a part of the machinery or total breakdown.

He must write a legible hand, and understand the first five rules of arithmetic and decimals.

He must be able to pass a creditable examination as to the various construction of various paddle and screw engines in general use, as to the details of the different working parts, external and internal, with each part.

First-class Engineers.

4th.—A candidate for a first-class Engineers' certificate of competency must be 22 years of age.

In addition to the qualifications required for a second-class Engineer—

He must either possess, or be entitled to a first-class Engineers' certificate of service, or in the event of his not being so possessed or entitled, he must have served for one year with a second-class Engineers' certificate of service.

He must be able to make rough working drawings of the different parts of the Engine and Boilers.

He must also be able to take off and calculate indicator diagrams.

He must also be able to calculate safety valves, pressures, and strength of the boilers.

He must be able to state the general proportions borne by the principal parts of the machinery to each other.

He must be able to explain the method of testing and altering the setting of the slide valves, and of testing the fairness of the paddle and screw shafts, and of adjusting them.

He must be conversant with surface condensation, superheating, and the working of steam expansively. His knowledge of arithmetic must include that of the mensuration of superficies and solids, and the extraction of the square root.

The examination will be partly *viva voce*, and partly by examination papers. It will be specially directed to the above points, and to the duties and business of an Engineer generally.

If the candidate passes the *viva voce* examinations creditably, a set of questions will be given to work out.

He will be allowed to work out these questions according to the methods he is accustomed to use, and he will be allowed five hours to perform the work, at the expiration

of which time, if he has not finished, he will be declared to have failed, unless the Local Marine Board see fit to extend the time.

Notices of the times and places at which the examinations for certificates of competency are to be held will be published.

Qualifications for Certificates of Service.

Every person who before the First of April, 1862, had served as first Engineer in a British Foreign-going Steam Ship of 100 nominal horse-power and upwards, and who attained, or attains the rank of Engineer in the service of her Majesty, or of the East India Company, is entitled to a first-class Engineers' certificate of service; and every person who, before the above-mentioned date, had served as second Engineer in any Foreign-going Steam Ship of 100 nominal horse-power or upwards; or as first or only Engineer in any other Steam Ship; or who has attained or attains the rank of first-class Assistant Engineer in the service of her Majesty, is entitled to a second-class Engineers' certificate of service.

Applications for certificates of service must be made on the printed form E (on page 22), to be obtained at once, free of charge, of the Registrar-General of Seamen, Adelaide Place, London Bridge, London, or of the Superintendent of any Mercantile Marine Office.

EXPLANATION OF THE SIGNS USED IN CALCULATION.

$+$	Signifies Addition, and is named *plus* as $2+3=5$ that is 2 added to 3 is equal to 5.
$-$	Signifies Subtraction, and is named *minus* or *less* as $5-2=3$, that is 2 taken from 5 the remainder is 3.
$\times$	Signifies Multiplication, and is named *into* or *Multiplied by* as $5\times5=25$, that is 5 multiplied by 5 is equal to 25
$\div$	Denotes Division, and is named *by* or *divided by* as $10\div2=5$ that is 10 divided by 2 is equal to 5.
$: :: :$	Signifies Proportion, as $2:3::4:6$, that is as 2 is to 3, so is 4 to 6.
$=$	Signifies Equality, as 12 pence is equal to One Shilling, 12d.$=$1 Shilling.
$\frac{2847}{92}$	Numbers placed with a line between them, shows that the Numbers above the line are to be divided by those below the line.
$\sqrt{}$	Denotes the Square Root of the Number as $\sqrt{9}=3$.
$\sqrt[3]{}$	Denotes the Cube Root of the Number as $\sqrt[3]{8}=2$.
2^2	Denotes the Number is to be Squared as $2\times2=4$.
2^3	Denotes the Number is to be Cubed as $2\times2\times2=8$.
2^4	Denotes the Fourth Power of the Number as $2\times2\times2\times2=16$.
2^5	Denotes the Fifth Power of the Number as $2\times2\times2\times2\times2=32$.

PROPORTION.

Simple proportion teaches when three numbers are given to find a fourth. The first term bears the same proportion to the second, as the third does to the fourth.

It is often called the rule of three, and from its usefulness it is sometimes called the golden rule.

Rule 1st.—Find out what is required, and write down that term for the third which is of the same name with the number sought.

Rule 2nd.—Consider whether the answer will be greater or less than the third term. If greater, place the less term for the first and the greater for the second. But if the answer will be less, place the greater term for the first and the less term for the second.

Rule 3rd.—Multiply the two last terms together and divide by the first, and the quotient will give the answer in the same name with that of the third term.

If 200 tons of coals are sufficient for 5 days consumption, how many tons will be used at the same rate of consumption in 9 days.

Here it is coals that is required, therefore coals is the third term, and in 9 days more will be used than in 5 days, therefore. 9 is the second term and 5 is the first.

Then as 5 : 9 : : 200 : 360 tons.—Answer.

$$\begin{array}{r} 200 \\ 9 \\ \hline 5)1800 \\ \hline 360 \end{array}$$

Proof as 9 : 5 : : 360 : 200 tons.

$$\begin{array}{r} 360 \\ 5 \\ \hline 9)1800 \\ \hline 200 \end{array}$$

The sign is as 5 is to 9, so is 200 to 360.

Or as above, as 5 : 9 : : 200 : 360.

Q. 2.—If 200 tons of coals are sufficient for 5 days consumption, how many days will it take to consume 250 tons.

In this question, days are required, therefore, days are the third term, and as it will take longer time than is given in the third term, 250 will be the second term and 200 the first.

Then as 200 : 250 : : 5 : 6 days 6 hours.

$$\begin{array}{r} 5 \\ \hline 200)1250 \\ \hline 6{\cdot}25 \end{array}$$

Q. 3.—If 8 cubic feet of cast iron weigh 1 ton 12 cwt. What will 24 cubic feet weigh.

As 8 : 24 : : 1 ton 12 cwt : 4 tons 16 cwt. [Answer.

$$\begin{array}{r} 20 \\ \hline 32 \\ 24 \\ \hline 128 \\ 64 \\ \hline 8)768 \\ \hline 20)96 \\ \hline 4 - 16 \text{ cwt.—Answer.} \end{array}$$

Or by Abrevation

$$\begin{array}{l} \text{as } \cancel{8} : \cancel{24} : : 1 \quad 12 \\ \quad 1 \quad 3 \qquad\quad 3 \\ \hline 4 - 16 \text{ cwt.} \end{array}$$

The figure 8 is cancelled by the Abreviation of 24 to 3, which shows the sum worked out with less than the half of the figures.

Q. 4.—A block of cast iron 2-feet square and 1-foot thick weigh 16 cwt., what will be the weight of a block of cast iron 3-feet square and 1-foot thick.

The block 2-feet square are $2 \times 2 = 4$-feet.

The block 3-feet square are $3 \times 3 = 9$-feet.

Then as 2-feet square : to 3-feet square : : 16

$$\begin{array}{ccc} 2 & 3 & 9 \\ \hline 4 & 9 & 4)144 \\ & & \overline{20)\ 36} \\ & & \overline{1 - 16} \text{ cwt.—Ans.} \end{array}$$

Or as $\cancel{4} : 9 : : \cancel{16}$

$$\begin{array}{r} 1 \quad 4 \\ 9 \\ \hline 20)36 \\ \hline 1 \quad 16 \end{array}$$

The first and third terms are Abreviated by 4.

The weight of a cubic foot of cast iron is calculated at 4 cwt., and the proportion of wrought iron to cast is as $1 : \cdot 95$ or $\frac{19}{20}$.

If the $\frac{1}{3}$ of 6 was 3, what would the $\frac{1}{4}$ of 20 be.

The third of 6 is 2 and the fourth of 20 is 5.

Therefore, as 2 the $\frac{1}{3}$ of 6 is to 3, so is the $\frac{1}{4}$ of 20 which is 5 to $7\frac{1}{2}$.

As $2 : 3 : : 5 : 7\frac{1}{2}$.

$$\begin{array}{r} 5 \\ \hline 2)15 \\ \hline 7\frac{1}{2} \end{array}$$

If $32\frac{1}{2}$ cubic feet of Steam at Atmospheric Pressure weigh 1 lb., what will be the weight of 12·13 cubic feet of Steam at the same pressure.

As $32\frac{1}{2} : 12 \cdot 13 : : 1 : \cdot 373$ of a pound.—Answer.

$$\begin{array}{r} 1 \\ \hline 32 \cdot 5)12 \cdot 13(\cdot 373 \\ 975 \\ \hline \end{array}$$

[OVER.]

```
 2380
 2275
 ----
  1050
   975
 ------
    75
```

If 12·13 cubic feet of Steam at Atmospheric Pressure is equal to the quantity required per minute, to give a Horse Power; what quantity of water will it require to supply a Boiler per Horse Power per hour?

32¼ cubic feet of Steam at Atmospheric Pressure equals 1 lb., and 62·5 lbs. are equal to 1 cubic foot, and 12·13=·373 of a pound.

As 1 minute is to 60 so is ·373 to 22½ lbs nearly

```
                              60
                           ------
                 62·5)22·380(·358 of a cubic foot per
                      18 75          [hour.—Answer.
                      -----
                       3 630
                       3 125
                       -----
                        5050
                        5000
```

COMPOUND PROPORTION.

In compound proportion, five terms are given to find a sixth, or seven to find an eighth term, &c.

This rule is not much used as two or more statings of simple proportion will give the answer sought.

Rule.—Write down the term for the third which is of the same with the number sought; proceed then with the first and second terms as in simple proportion, take the other two of the same kind with each other and place them under the first and second term. Multiply the product of of the second terms by the third term for a dividend, divide by the product of the first terms multiplied together, and the quotent is the Answer and of the same name with the third term.

Example.—Some repairs of the Engines have occupied Eight men $3\frac{1}{2}$ weeks, and has cost £35 10s. for wages. Some large repairs are necessary which it is to be expected will occupy Eleven Men 3 weeks, how much will it require to pay them at the same rate of wages.

Money is required, therefore, money will be the third term.

As	8	: 11	: : £35	10s.		: £41 16 $9\frac{1}{4}$ $\frac{5}{7}$
	$3\frac{1}{2}$	: 3		3		
	24	33	106	10		
	4			11		
	28	28	(4)1171	10		
			(7) 292	17	6	
			£41	16	$9\frac{1}{4}$ $\frac{5}{7}$	

Or the above sum will appear more simple if we reduce the sums in this form, 8 men for $3\frac{1}{2}$ weeks are equal to 28 men for 1 week, and 11 men for 3 weeks are equal to 33 men for 1 week. So that if it cost £35 10s. for 28 men 1 week: how much will it cost 33 men 1 week?

```
As 28 : 33 : : £35  10s. : £41  16  9¼ 5/7
                  20
                 ----
                 710
                  33
                 ----
                2130
               2130
28÷=4×7        -----
              4)23430
              ---------
               7)5857  6
              ----------
              20)836  9¼ 5/7
              --------------
                £41  16  9¼ 5/7
```

SO MUCH PER CENT.

The word Cent is used in places abroad instead of the word hundred in the English language, hence the little difficulty to be overcome so as to be familiar with a word that is seldom used.

We should have passed by this Rule of Interest as it is called; but the revolutions of the Screw propeller in many cases has a slip and it is generally calculated at so much per cent., or what is the same thing so much per 100, also the deterioration of coals are expressed in the same way.

When speaking of 5 per cent. loss in coals: this means 5 tons loss for every 100 tons, which would be to multiply the whole quantity of coals by 5 and divide by 100, or to take from the whole quantity $\frac{1}{20}$ It will be easily seen that $\frac{5}{100}$ are equal to $\frac{1}{20}$, and 50 per cent. is equal to the half of the whole quantity referred to, whether it is increased or decrease, and 100 per cent. or as it is some times called cent per cent; if a decrease, the total loss of whatever it may refer to: but if an increase, it is a gain equal to the original amount.

For example, a man starts business with £500, and at the end of two years his profits are equal to 100 per cent. or at the rate of 50 per cent. per annum, or further the slip of the Screw is 100 per cent. while the Ship is made fast in Harbour. The Ship remaining stationary while the Screw goes round.

The revolutions of a Screw propeller are 40,000 in 24 hours, and the pitch of the Screw is 20-feet. What distance has the Ship run during that time. Allowing slip equal to $7\frac{1}{2}$ per cent., and 6080 for every nautical mile.

[OVER.]

miles

$\frac{40000 \times 20}{6080} = 131{\cdot}58$ distance run by Screw.

40,000
      20
———
6080)800;000(131·58
  6080
  ———
  19200
  18240
  ———
    9600
    6080
    ———
    35200
    30400
    ———
     48000
     48640

$131{\cdot}58 - 9{\cdot}86 = 121{\cdot}72$ distance run [by Ship.

Then as $100 : 7\frac{1}{2} :: \frac{1}{2})131{\cdot}58 : 9{\cdot}86$

      $7\frac{1}{2}$
    ———
    921 06
      65 79
    ———
100)986 85
    ———
      9·86 Slip.
    131·58
    ———
    121·72 distance run.

VULGAR FRACTIONS.

A Fraction is something less (or any part of one) or whole number. To understand the nature of Fractions—one or something else must be considered as a whole divided into several equal parts, and is represented by two numbers placed the one below the other, with a line between them, thus $\frac{1}{4}$, or one quarter. The figure on the top of the line is called the numerator, and the figure under the line is called the denominator. The denominator shows how many parts the whole number is divided into, and the numerator shows how many of these parts the fractor represents.

There are four sorts of Vulgar Fractions, namely:—proper, improper, simple and mixed.

A Proper Fraction is when the numerator is less than the denominator, as $\frac{1}{2}$, $\frac{5}{8}$, $\frac{6}{12}$, $\frac{9}{11}$.

An Improper Fraction is when the numerator is equal to, or greater than the denominator as $\frac{2}{2}$, $\frac{4}{3}$, $\frac{18}{6}$, &c.

A Simple Fraction is that which consists of a simple numerator and a simple denominator, and is either proper or improper, as $\frac{6}{7}$, $\frac{7}{8}$, $\frac{11}{9}$, &c.

A Compound Fraction is a fraction of a fraction, as $\frac{3}{4}$ of $\frac{2}{5}$.

A Mixed Number is composed of an integer and fraction annexed as $7\frac{3}{4}$.

Fractions in many cases require to be reduced before they can be either added, subtracted, multiplied, or divided. Therefore we begin with reduction.

Reduce $4\frac{3}{4}$ to a simple fraction.

$$\begin{array}{l} 4\frac{3}{4} \\ 4 \\ \hline \frac{19}{4}.\text{—Answer.} \end{array}$$

The above is done by multiplying 4 whole numbers by 4 which are 16 quarters, and adding the 3 quarters which make the fraction $\frac{19}{4}$ equal to $4\frac{3}{4}$

REDUCTION OF VULGAR FRACTIONS.

Reduce $5\frac{7}{8}$ to a simple or improper fraction.

$$\begin{array}{l} 5\frac{7}{8} \\ 8 \\ \hline \frac{47}{8}.\text{—Answer.} \end{array}$$

$\frac{47}{8}$ are equal to $5\frac{7}{8}$—if we want to know how many eight parts there are in $5\frac{7}{8}$-inches, the above would be the answer, or if we wished to know how many inches are in $\frac{47}{8}$, divide the figures on the top of the line by the bottom figure thus $\begin{array}{l} 8)\underline{47} \\ \quad 5\frac{7}{8} \end{array}$. It is evident therefore, that to reduce an improper fraction to a whole or mixed number is the reverse of reducing it to an improper fraction

To reduce fractions of different denominators to others of equal value. Multiply each numerator by all the denominators except its own for a numerator, and all the denominators for a common denominator.

Reduce $\frac{1}{2}$, $\frac{2}{3}$, and $\frac{3}{4}$ to a common denominator. The numerator of $\frac{1}{2}$ is one, and the denominators of the other two fractions are 3 and 4.

Therefore $1 \times 3 \times 4$ are equal 12, this is the new numerator for $\frac{1}{2}=\frac{12}{24}$.

And $2 \times 3 \times 4$ are equal to 24, this is the new common denominator.

And $2 \times 2 \times 4$ are equal to 16, this is the new numerator for $\frac{2}{3}=\frac{16}{24}$.

And $3 \times 3 \times 2$ are equal to 18, this is the new numerator for $\frac{3}{4}=\frac{18}{24}$.

It will be evident from the above changes of numerator and denominator, that it does not change the value of the fraction as $\frac{12}{24}$ or $\frac{6}{12}$ or $\frac{1}{2}$ of any number or thing that can be divided into parts as the same value, while in this changed form they can be either added, substracted, multiplied, or divided at will.

Reduce $\frac{5}{6}$, $2\frac{3}{5}$ and 4 to a common denominator.

$$\begin{array}{l} 2\frac{3}{5} \\ 5 \\ \hline \frac{13}{5} \end{array}$$

Then $\frac{5}{6}$ $\frac{13}{5}$ and 4 are equal to $\frac{5}{6}$ $\frac{13}{5}$ and $\frac{4}{1}$.

Therefore $5 \times 5 \times 1$ equal to 25, the new numerator for $\frac{5}{6}$ equal to $\frac{25}{30}$.

Therefore $13 \times 6 \times 1$ equal to 78, the new numerator for $\frac{13}{5}$ equal to $\frac{78}{30}$.

Therefore $4 \times 6 \times 5$ equal to 120, the new numerator for $\frac{4}{1}$ equal to $\frac{120}{30}$.

Therefore $5 \times 6 \times 1$ equal to 30, the new common denominator.

When a whole number or numbers has to be reduced to a fraction, its denominator is one as shown above.

Reduce 7 to a fraction whose denominator is 9

7×9 equal $\frac{63}{9}$.—Answer.

Reduce $\frac{63}{9}$ to its equivalent number

$\frac{63}{9}=7$.—Answer.

$$\begin{array}{r} 9)63 \\ \hline 7 \end{array}$$

Reduce $\frac{1}{2}$ of $\frac{2}{3}$ of $\frac{3}{4}$ to a simple fraction.

$\frac{1 \times 2 \times 3}{2 \times 3 \times 4}=\frac{6}{24}$ equal to $\frac{1}{4}$.—Answer.

Or the easiest way is to cancel the 2 and 3 on each side of the line, and there will be left the figure 1 on the top, and the figure 4 on the underside of the line, which is the Answer required.

Example $\frac{1\times\cancel{2}\times\cancel{3}}{\cancel{2}\times\cancel{3}\times4}=\frac{1}{4}$.—Answer.

This method saves labour with less liability to make mistakes.

Reduce $\frac{1}{2}$ of $\frac{2}{3}$ of $\frac{3}{4}$ of $\frac{4}{5}$ of $\frac{5}{6}$ of $\frac{6}{7}$ of $\frac{7}{8}$ of $\frac{8}{9}$ of $\frac{9}{10}$ of a simple fraction.

$\frac{1\times2\times3\times4\times5\times6\times7\times8\times9}{2\times3\times4\times5\times6\times7\times8\times9\times10}=\frac{362880}{3628800}=\frac{1}{10}$.—Answer.

Thus 362880 divided by itself is 1 time.

And 3628800 divided by 362880 is 10 times

equal $\frac{1}{10}$ as above.—Answer.

```
     1
     2
    --
     2
     3
    --
     6
     4
    --
    24
     5
   ---
   120
     6
   ---
   720
     7
  ----
  5040
     8
 -----
 40320
     9
------
362880
```

The numerator. The denominator may be found by adding a cypher.

A owes B $\frac{1}{2}$ of $\frac{2}{3}$ of $\frac{3}{4}$ of $\frac{4}{5}$ of $\frac{5}{6}$ of $\frac{6}{7}$ of $\frac{7}{8}$ of $\frac{8}{9}$ of $\frac{9}{10}$ of £1 how much does A owe B.

$\frac{1\times\cancel{2}\times\cancel{3}\times\cancel{4}\times\cancel{5}\times\cancel{6}\times\cancel{7}\times\cancel{8}\times\cancel{9}}{\cancel{2}\times\cancel{3}\times\cancel{4}\times\cancel{5}\times\cancel{6}\times\cancel{7}\times\cancel{8}\times\cancel{9}\times10}=\frac{1}{10}$ of £1=2 shillings. [Ans.

In the working of sums like the above, the money is multiplied by the figures on the top of the line, and divided by those under the line; but to multiply any number by a few figures and divide by the same figures, must be evident (unless it is for practice) is labour lost. Therefore all the figures on the top of the line are cancelled except the figure 1. And all those on the underside except 10 which leaves 1 for the numerator and 10 for the denominator, which gives the Answer, namely :—$\frac{1}{10}$ and $\frac{1}{10}$ of £1 is 2 shillings.

Reduce $\frac{3}{7}$ of $\frac{4}{5}$ to a simple fraction.

$$\frac{3\times4}{7\times5}=\frac{12}{35}.\text{—Answer.}$$

Reduce $\frac{3}{4}$ of a pound sterling to the fraction of a penny.

$$\frac{3\times20\times12}{4\times1\times1}=\frac{720}{4}=\frac{180}{1}.$$

Reduce $\frac{2}{7}$ of a cwt. to the fraction of a pound—Avoirdupois.

$$\frac{2\times4\times28}{7\times1\times1}=\frac{224}{7}=\frac{32}{1}.\text{— Answer.}$$

Or by abreviation cancel the 7 and abreviate 28 by 7 will be as under.

$$\frac{2\times4\times\overset{4}{\cancel{28}}}{\underset{1}{\cancel{7}}\times1\times1}=\frac{32}{1}.$$

Reduce $\frac{3}{8}$ of a crown to the fraction of a guinea.

$$\frac{3\times5}{8\times21}=\frac{15}{168}=\frac{5}{56}.$$

Or by cancelling $\frac{\cancel{3}}{8}\times\frac{5}{\underset{7}{\cancel{21}}}=\frac{5}{56}\cdot$

Reduce 3 shillings and sixpence to the fraction of a pound sterling.

$$3\,..\,6-\frac{\overset{7}{\cancel{42}}\times1}{\underset{2}{\cancel{12}}\times20}=\frac{7}{40}$$

ADDITION OF VULGAR FRACTIONS.

Prepare Fractions as has been shown by reducing them to a common denominator. As none but similar or like parts can be added together. Cwts. and quarters are not placed in the same column for addition; so it is with fractions.

Add $\frac{5}{8}$ and $\frac{6}{8}$ of a pound sterling together.

$\frac{5}{8}\times\frac{6}{8}=\frac{11}{8}$ of a pound.—Answer.

When the numerator and the denominator are equal, then the amount is equal to one of whatever it represents, therefore $\frac{11}{8}$ is equal to $1\frac{3}{8}$ of a pound.

8)11(£1 7s. 6d.—Answer.
8
—
3
20
—
60
56
—
4
12
—
48
48

Add $\frac{5}{7}$ of a pound sterling to $\frac{4}{5}$ of a shilling.

$\frac{5\times20}{7\times1}=\frac{100}{7}$ of a shilling.

Or $\frac{5}{7}\times\frac{20}{1}=\frac{100}{7}$.

$\frac{4}{5}\times\frac{100}{7}=\frac{28}{35}+\frac{500}{35}=\frac{528}{35}$ [of a shilling.

7)100(14s. $3\frac{1}{4}\,\frac{5}{7}$
7
—
30
28
—
2
12
—

As $\frac{4}{5}\times\frac{12}{1}=\frac{48}{5}$.

35)528(15s. $1\frac{0}{4}\,\frac{4}{35}$.—Answer.
35
—
178
175
—
3
12
—

24 | 5)48 | 36
21 | $9\frac{1}{2}\frac{2}{5}$ | 35
3 | | 1
4 | | 4
12 | | 4

s. d.
Then 14 $3\frac{1}{4}\frac{5}{7}$
0 $9\frac{1}{2}\frac{2}{5}$

£0 15 $1\frac{0}{4}\frac{4}{35}$.—Answer.

Add $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ and $\frac{1}{5}$ together.

$\frac{1\times1\times1\times1}{2\times3\times4\times5}=\frac{60}{120}+\frac{40}{120}+\frac{30}{120}+\frac{24}{120}=\frac{154}{120}=1\frac{17}{60}$.—Answer.

Or $\frac{1}{2}=\frac{30}{60}$

$\frac{1}{3}=\frac{20}{60}$

$\frac{1}{4}=\frac{15}{60}$

$\frac{1}{5}=\frac{12}{60}$

$\frac{77}{60}=1\frac{17}{60}$

Add $\frac{4}{5}$ of a ton, $\frac{2}{3}$ of a cwt, and $\frac{5}{8}$ of a pound together.

$$\frac{\overset{4}{4\times\cancel{20}}\times4\times28}{\cancel{5}\times1\times1\times1}= \;=1792\text{ lbs.}$$

$\frac{2}{3}\times\frac{4}{1}\times\frac{28}{1}$ 74 $10\frac{2}{3}$

$\frac{5}{8}\times\frac{16}{1}$ 0 10

1867 $4\frac{2}{3}$ oz.

2, 4, 8, 28, 3)224, 74 $10\frac{2}{3}=\frac{2}{3}$ of a cwt.

4, 4, 16, 4, 64, 28, 512, 128, 1792 $=\frac{4}{5}$ of a ton.

5, 16, 8)80, 10 oz. $=\frac{5}{8}$ of a pound.

Or $\frac{4}{5}\times\frac{20}{1}\times\frac{4}{1}\times\frac{28}{1}=\frac{8960}{5}=\frac{1792}{1}$ of a pound or $\frac{4}{5}$ of a ton.

And $\frac{2}{3}\times\frac{4}{1}\times\frac{28}{1}=\frac{224}{3}$ of a pound or $\frac{2}{3}$ of a cwt.

Then $\frac{1792}{1}\times\frac{224}{3}\times\frac{5}{8}=\frac{43008}{24}+\frac{1792}{24}+\frac{15}{24}=\frac{44815}{24}=1867$ lbs. $4\frac{2}{3}$ oz.—Answer.

Or 1867 lbs. $4\frac{2}{3}$ oz. = 16 cwt. 2 qrs. 19 lbs. $4\frac{2}{3}$ oz.—Ans.

SUBTRACTION OF VULGAR FRACTIONS.

Rule.—As Fractions having the same denominator can only be added together, so fraction must have the same denominator to be subtracted from each other. There is therefore the same reason for preparing fractions for subtraction as has been shown in addition.

Subtract $\frac{3}{4}$ from $\frac{7}{8}$.

$$\frac{3\times 7}{4\times 8}=\frac{24}{32}-\frac{28}{32}=\frac{4}{32}\text{ or }\frac{1}{8}.$$

It is well known that $\frac{3}{4}$ and $\frac{6}{8}$ are of the same value, and this fraction so altered would give the answer as above, without reducing the fractions to the common denominator of 32. But the object of reducing the two fractions, are for plainness and according to rule.

Four men represented by A. B. C. and D., purchase a business ; A has $\frac{1}{4}$, B $\frac{1}{3}$, C $\frac{3}{8}$, and D the remainder. Required D's. share

$$\frac{1}{4}+\frac{1}{3}+\frac{3}{8}=\frac{24}{96}+\frac{32}{96}+\frac{36}{96}=\frac{92}{96}\text{ A. B. and C's. shares.}$$

A. B. and C's. shares are 92 parts of 96—therefore 92 subtracted from 96 leaves $\frac{4}{96}$ for D's. share, or at its lowest term is $\frac{1}{24}$.

The denominator 96 shows how many parts the business is divided into. And A. B. and C's. shares, when subtracted, gives the remainder as D's. share

$$\frac{92}{96}-\frac{96}{96}=\frac{4}{96}=\frac{1}{24}.\text{—Answer.}$$

Or A. has $\frac{6}{24}$, B. $\frac{8}{24}$, C. $\frac{9}{24}$, and D. $\frac{1}{24}=\frac{24}{24}=1$.

What is the difference between $\frac{4}{7}$ of a cwt. and $\frac{7}{10}$ of a ton.

$$\frac{4\times 4\times \overset{4}{\cancel{28}}}{\cancel{7}\times 1\times 1}=64\text{ lbs.}$$

$$\frac{7\times \overset{2}{\cancel{20}}}{\underset{1}{\cancel{10}}\times 1}=\overset{1}{}=$$

cwt.	qrs.	lbs.	
0	2	8	(or $\frac{4}{7}$ of a cwt.)
14	0	0	$\frac{7}{10}$ of a ton.
13	1	20.	—Answer.

The difference is 13 cwt. 1 qr. 20 lbs.

In working this sum, 7 is cancelled with the abreviation of 28 to 4, and 10 is cancelled with the abreviation of 20 to 2.

What is the difference between a half inch square and the half of a square inch.

A square inch contains $\frac{64}{8}$ and the half of this is $\frac{32}{8}$, and a half inch square is the fourth of a square inch $=\frac{16}{8}$.

Therefore $\frac{32}{8}-\frac{16}{8}=\frac{16}{8}$ difference.—Answer.

or

$$\begin{aligned} \tfrac{1}{2} \text{ of 1 square inch } &= \tfrac{1}{2} \\ \tfrac{1}{2} \text{ inch square } = \tfrac{1}{2}\times\tfrac{1}{2} &= \tfrac{1}{4} \\ \hline & \tfrac{1}{4}. \end{aligned}$$

And a $\frac{1}{4}$ of a square inch is equal to 16 square 8 parts.

MULTIPLICATION OF VULGAR FRACTIONS.

Rule.—Multiply all the numerators together for a numerator, and all the denominators for a denominator—which will give the product required

Multiply $\frac{1}{2}$ by $\frac{1}{2}$, thus $\frac{1\times1}{2\times2}=\frac{1}{4}$.—Answer.

To a youth who has left school for a year, at the age of 14 years, and is serving his apprenticeship. It frequently happens that he forgets a large part of what he was taught at school, and Arithmetic comes in for its full share. It does not appear that the mind has been impressed with the truth that all sums does not increase by multiplication; although it does so in many cases, and the pupil has generally been working out sums that

shew multiplication increased their value. Still the above sum of $\frac{1}{2}$ multiplied by $\frac{1}{2}$ shows its value is decreased. All sums above 1 and multiplied by something more than 1, increases its value, but 1 multiplied by 1 there is no increase, for the plain reason that is 1 times 1; but to multiply anything by something less than a whole number decreases its value: thus 1 multipled by a $\frac{1}{2}$ the product is a $\frac{1}{2}$, and $\frac{1}{4}$ multiplied by $\frac{1}{4}$ the product is $\frac{1}{16}$—in the former it is $\frac{1}{2}$ times 1 and in the latter it is a $\frac{1}{4}$ times $\frac{1}{4}$. In the addition of fractions their product is an increase, but as has been shown the multiplication of any sum by something less than 1, its value is decreased. The addition of all sums up to the figure 2 are greater than their multiplication at 2, the sums are equal, for 2 times 2 are 4, and 2 added to 2 are 4; but if we multiply $1\frac{1}{2}$ by $1\frac{1}{2}$ the product is $2\frac{1}{4}$, and if we add $1\frac{1}{2}$ to $1\frac{1}{2}$ the product is 3. Again if any two figures be multiplied together whose value are more than 2, their multiplication will be more than their addition.

All fractions if their value is less then 1, whether they be decimals or vulgar fractions when multiplied together their value is decreased. It is a common error in the workshop to believe that whenever multiplication takes place an increase follows. This shows that a suitable explanation of the principle has not been taught at school, and we know that at those schools at which Engineers' (generally) receive their instruction when young, that this is only too common.

Multiply $\frac{1}{2}$ by $\frac{2}{3}$ and $\frac{3}{4}$.

$$\frac{1 \times 2 \times 3}{2 \times 3 \times 4} = \frac{6}{24} = \frac{1}{4}.\text{—Answer.}$$

But if the 2 and 3 on the top and underside of the line are cancelled, there will only remain 1 on the top line and 4 underneath the line which gives the Answer

required. This has been already shown in the example of reduction of fractions.

Multiply $\frac{5}{6}$ by $\frac{4}{7}$.

$$\frac{5\times\overset{2}{\cancel{4}}}{\underset{3}{\cancel{6}}\times 7}=\frac{10}{21}.\text{—Answer.}$$

Required the weight of a log of timber $6\frac{1}{4}$-feet long, $3\frac{5}{8}$-feet broad, and $2\frac{1}{3}$-feet thick, at $27\frac{1}{8}$-lbs. per cubic foot.

$6\frac{1}{4}\times 3\frac{5}{8}\times 2\frac{1}{3}\times 27\frac{1}{8}=12$ cwt., 3 qrs., 6 lbs.—Answer.

$6\frac{1}{4}=\frac{25}{4}$ then $\frac{25}{4}\times\frac{29}{8}\times\frac{7}{3}\times\frac{217}{8}=12$ cwt., 3 qrs., 6 lbs.

$3\frac{5}{8}=\frac{29}{8}$

$2\frac{1}{3}=\frac{7}{3}$

$27\frac{1}{8}=\frac{217}{8}$

$$\begin{array}{r} 25\\ 29\\ \hline 225\\ 50\\ \hline 725\\ 7\\ \hline 5075\\ 217\\ \hline 35525\\ 5075\\ 10150\\ \hline \end{array}$$

	cwt.	qrs.	lbs.
$4\times 8\times 3\times 8 = 768)1101275(1434 \div 112 =$	12	3	6

To multiply a whole number (or anything equal to or more than 1) by a fraction, is to multiply the whole number by the numerator and divide by the denominator.

Multiply 4 by $\frac{7}{9}$.

$4\times\frac{7}{9} = 3\frac{1}{9}$.—Answer.

$$\begin{array}{r} 4\\ 7\\ \hline 9)28\\ \hline 3\frac{1}{9} \end{array}$$

Multiply $4\frac{1}{3}$ by $\frac{4}{9}$.

$$\begin{array}{r} 4\frac{1}{3} \\ 3 \\ \hline 13 \\ \hline 3 \end{array} \qquad 4\tfrac{1}{3} = \tfrac{13}{3} \times \tfrac{4}{9} = \tfrac{52}{27} = 1\tfrac{25}{27}.\text{—Answer.}$$

DIVISION OF VULGAR FRACTIONS.

Division being the reverse of multiplication, and it has been shown in multiplication of proper fractions that a decrease in value follows—so in division an increase follows—this being the opposite of the two rules, viz:—multiplication and division when applied to whole numbers. It is therefore very natural for those pupils who have been taught to work out problems by a rule, but the principal never been explained; and when a year or two away from school the rule is forgotten, and so is this portion of their education.

It has been shown in multiplication of fractions that $\frac{1}{2}$ multiplied by $\frac{1}{2}$ the product is $\frac{1}{4}$; but in dividing $\frac{1}{2}$ by $\frac{1}{2}$ the quotient is 1. We explained this by showing that it is $\frac{1}{2}$ times $\frac{1}{2}$ that produced $\frac{1}{4}$. And now in division it is how many times is $\frac{1}{2}$ to be got in a $\frac{1}{2}$, which is clear to every one is 1 time.

This difficulty lies in our mode of expression in its want of comprehensiveness, not in the application of these rules to fractions. We have shown that a $\frac{1}{4}$ multiplied by $\frac{1}{4}$ is $\frac{1}{16}$, but $\frac{1}{4}$ divided by $\frac{1}{4}$ the quotient is 1; this we have to say again is how many times does $\frac{1}{4}$ contain $\frac{1}{4}$ the quotient is 1 time. In multiplication it is shown that the value of fractions is to be found by multiplying the figures above the line together called the numerators and the figures below the line called the denominators. But in division if the fractions have the same denominators, then the numerator of the fractions divided by each other will give the Answer. Thus $\frac{5}{3}$ divided by $\frac{3}{3}$, the quotient is $1\frac{2}{3}$, but should the denominators be different from each other, thus divide $\frac{2}{3}$ by $\frac{1}{2}$ they may be reduced to a common denominator.

$\frac{2\times 2}{3\times 2} = \frac{4}{6}\ \frac{3}{6}$ then how many times $\frac{3}{6}$ is contained in $\frac{4}{6}$ the Answer $1\frac{1}{3}$.

Or to invert the divisor thus $\frac{2}{1}\times\frac{2}{3}$ equal $\frac{4}{3} = 1\frac{1}{3}$.

Divide $\frac{7}{9}$ by $\frac{2}{7}$ invert the divisor.

$$\frac{7}{2}\times\frac{7}{9} = \frac{49}{18} = 2\frac{13}{18}\ 18 \div 49 = 2\frac{13}{18}.\text{—Answer.}$$

DECIMAL FRACTIONS.

Decimal Arithmetic in a general sense denotes the common arithmetic in which we count by collecting units into periods of ten,—tens into hundreds,—hundreds into thousands, &c.

The necessity of reducing fractions to a common denominator, before proceeding to find their difference, has called for some method expressing fractions having a known common denominator; such a method has been devised and constitute the decimal system.

The decimal system is a unit divided into tenths, one of these tenths divided into tenths again called hundreds, and one of these hundreds divided into tenths called thousands, and so on taking the name of tenths from the word decim.

A decimal fraction having a known common denominator, the numerator is expressed only, and that by placing a point before it, the figure next the point is tenths, the next hundreds, the next thousands, and the next ten thousand parts

·5 denotes 5 tenths of 1, and can be placed with its denominator at pleasure as $\frac{5}{10}$ equal to $\frac{1}{2}$, but as the denominators are known, the fraction of $\frac{1}{2}$ is expressed thus ·5 in decimals.

·75 denotes 7 tenths, and 5 hundred parts of 1 equal to $\frac{3}{4}$, because its denominator is 100 thus $\frac{75}{100}$.

·50 denotes 50 hundreds, but is of the same value as 5 tenths or $\frac{1}{2}$—so that placing cyphers to the right of decimals does not alter their value—but to place a cypher next to the point thus ·05 decreases the value of the

fraction from 5 tenths to 5 hundreds parts of one, and ·005 is 5 thousand parts of 1.

·25 is equal to $\frac{25}{100}$ and its lowest term is $\frac{1}{4}$.
·5 is equal to $\frac{5}{10}$ and its lowest term is $\frac{1}{2}$.
·75 is equal to $\frac{75}{100}$ and its lowest term is $\frac{3}{4}$.
·125 is equal to $\frac{125}{1000}$ and its lowest term is $\frac{1}{8}$.

REDUCTION OF DECIMALS.

To reduce vulgar fractions to decimals. Place the numerator for a dividend to be divided by the denominator, annexing cyphres to the dividend while there is a remainder. There are exceptions to this rule in reducing certain fractions that are called infinate or interminate on reducing them to decimals.

Reduce $\frac{1}{2}$ to a decimal.
2)1·0
·5.—Answer.

Reduce $\frac{1}{4}$ to a decimal.
4)1·00
·25.—Answer.

Reduce $\frac{3}{4}$ to a decimal.
4)3·00
·75.—Answer.

Reduce $\frac{4}{5}$ to a decimal.
5)4·0
·8.—Answer.

Reduce $\frac{1}{3}$ to a decimal.
3)1·0
$\cdot 33\dot{3}$.—Answer

This is called a repeating decimal, and is called interminate; in adding or multiplying by these, 1 is carried for every 9.

Reduce $\frac{2}{9}$ to a decimal.

$$9)\underline{2{\cdot}0}$$
$$\cdot\dot{2}.\text{—Answer.}$$

Reduce $\frac{2}{3}$ to a decimal.

$$3)\underline{2{\cdot}0}$$
$$\cdot\dot{6}.\text{—Answer.}$$

Reduce $\frac{1}{9}$ to a decimal.

$$9)\underline{1{\cdot}0}$$
$$\cdot\dot{1}.\text{—Answer.}$$

Reduce $\frac{1}{6}$ to a decimal.

$$6)\underline{1{\cdot}0}$$
$$\cdot1\dot{6}.\text{—Answer.}$$

These repeating decimals, 1 should be carried for every 9, instead of 1 for every 10.

It has been stated in the working of vulgar fractions, that if we multiply any sum, and then divide it by the same figure, the sum will be left in its original value; and unless it is done for learning—for finding proof—or by way of practice, it will be so much time lost. If any of these repeating decimals are proved to see if the dividing of them are correct—multiply by the divisor and carry 1 for every 9 in multiplying the figure on the right.

Example.
$$3)\underline{1{\cdot}000}$$
$$\cdot33\dot{3}$$
$$\underline{3}$$
$$1{\cdot}000$$

Reduce $\frac{6}{7}$ to a decimal.

$$7)\underline{6{\cdot}00000000000000}$$
$$\cdot\dot{8}5714\dot{2}8571428 57$$

This is called a circulating decimal; after 6 figures the same figures return again, and like the spliting of a hair and taking the half of the remainder of which there is no end, might be carried on to infinatum: although the exact

decimal is not found for $\frac{6}{7}$, and many others of a similar kind; still four or five places (or figures) are considered sufficient for general purposes.

To reduce Shillings, Pence and Farthings to the decimal of a Pound. Begin with the lowest value first. Farthings as the denominator of the figure 4; Pence the denominator of 12; and Shillings the denominator of 20.

Reduce 6¾d. to the decimal of a Shilling.

$$\begin{array}{l} 4)3{\cdot}00 \\ \hline 12)6{\cdot}75 \\ \hline \quad {\cdot}5625.\text{—Answer.} \end{array}$$

Reduce 12s. and 6¾d. to the decimal of a Pound sterling. The Pound is divided here into one million parts, and 12s. and 6¾d. are ·628125 of these parts equal to $\frac{628125}{1000000}$ of a Pound.

$$\begin{array}{l} 4)3{\cdot}00 \\ \hline 12)6{\cdot}75 \\ \hline 20)12{\cdot}5625 \\ \hline \quad {\cdot}628125.\text{—Answer.} \end{array}$$

What is the value of ·628125 decimal of 1 Pound sterling

$$\begin{array}{r} {\cdot}628125 \\ 20 \\ \hline 12{\cdot}562500 \\ 12 \\ \hline 6{\cdot}750000 \\ 4 \\ \hline 3{\cdot}000000 \end{array} \quad = 12\text{s. } 6\tfrac{3}{4}\text{d.—Answer.}$$

To find the value of ·628125 of a Pound, is the reverse of reducing 12s. 6¾d. to this decimal, keeping the same number of decimal places counting from right to left.

Reduce 8 ounces to the decimal of a pound Avoirdupois, 16 ounces to the lb.

$$\begin{array}{r} 16)8{\cdot}0 \\ \hline {\cdot}5. \end{array}$$—Answer.

Reduce 14 lbs. 8 ozs., to the decimal of a quarter.

$$\begin{array}{r} 16)\ 8{\cdot}0 \\ \hline 28)14{\cdot}5 \\ \hline {\cdot}5\dot{1}7857\dot{1}4\dot{2}. \end{array}$$—Answer.

Reduce 3 qr. $9\frac{1}{3}$ lbs., to the decimal of a cwt.

$$\begin{array}{r} 3)1{\cdot}00 \\ \hline 28)9{\cdot}3\dot{3} \\ \hline 4)3{\cdot}3\dot{3} \\ \hline {\cdot}8\dot{3}. \end{array}$$—Answer.

What is the value of ${\cdot}8\dot{3}$ of a cwt.

$$\begin{array}{r} {\cdot}83\dot{3} \\ 4 \\ \hline 3{\cdot}33\dot{3} \\ 4 \\ \hline 1{\cdot}33\dot{3} \\ 7 \\ \hline 9{\cdot}33\dot{3} \end{array}$$

3 qrs., $9\frac{1}{3}$ lbs.—Answer.

$28 \times = 4 \times 7$

The repeater is multiplied according to rule, namely:—carrying 1 for every 9 in the figure on the right.

$$\frac{9{\cdot}333}{999} = \frac{1}{3}.$$

Reduce 6 cwt. 1 qr., to the decimal of a ton.

$$\begin{array}{r} 4)1{\cdot}00 \\ \hline 20)6{\cdot}25 \\ \hline {\cdot}3125 \end{array}$$ decimal of a ton.—Answer.

Reduce $6\frac{4}{8}$ inches to the decimal of a foot.

$$\begin{array}{r} 8)\underline{4\cdot} \\ 12)\underline{6\cdot5} \\ \cdot5416\dot{6} \end{array}$$

decimal of a foot.—Answer.

What is the value of $\cdot5416\dot{6}$ of a foot.

$$\begin{array}{r} \cdot5416\dot{6} \\ 12 \\ \hline 6\cdot50000 \\ 8 \\ \hline 4\cdot00000 \end{array} = 6\tfrac{4}{8} \text{ inches.}$$

Reduce 13s. $6\frac{3}{4}$d. to the decimal of a Pound sterling.

Farthings in one Penny	4)	3·00
Pence in one Shilling	12)	6·75
Shillings in one Pound	20)	13·5625
		·678125 decimal of a Pound [= 13s. $6\frac{3}{4}$d.

Reduce $4\frac{1}{2}$ inches to the decimal of a foot.

$$\begin{array}{r} 2)\underline{1\cdot0} \\ 12)\underline{4\cdot5} \\ \cdot375 \end{array}$$

·375.—Answer.

ADDITION OF DECIMALS.

Rule.—In adding decimals together, place the decimal point directly under each other, and proceed as in simple addition, if the decimals are finites. But if they are repeaters, carry the repeaters one figure beyond the finite, and carry by 9 or 1 for every 9 as has been shown in reduction.

Add together 47·894 + ·05278 + 493·0 and ·7854.

$$\begin{array}{r} 47{\cdot}894 \\ {\cdot}05276 \\ 493{\cdot}0 \\ {\cdot}7854 \\ \hline 541{\cdot}73216 \end{array}$$

Add together $5{\cdot}33\dot{3} + 479{\cdot}25 + {\cdot}0425 + 87{\cdot}1\dot{1} $ and $0{\cdot}166\dot{6}$.

$$\begin{array}{r} 5{\cdot}33333 \\ 479{\cdot}25 \\ 0{\cdot}0425 \\ 87{\cdot}11111 \\ 0{\cdot}16666 \\ \hline 571{\cdot}9036\dot{1} \end{array}$$

The repeaters are carried a figure beyond the finites and one is carried for 9.

The addition of decimals are so simple that two examples are sufficient.

SUBTRACTION OF DECIMALS.

Proceed as in addition, by placing the decimal point directly under each other and then subtract the lesser from the greater as in simple subtraction.

Find the difference between 687 and ·687.

$$\begin{array}{r} 687\cdot \\ \cdot 687 \\ \hline 686\cdot 313 \end{array}$$

686·313.—Answer.

Find the difference between 56·793 and 5·6793.

$$\begin{array}{r} 56\cdot 793 \\ 5\cdot 6793 \\ \hline 51\cdot 1137 \end{array}$$

51·1137.—Answer.

Find the difference between 397·04 and 296·407.

$$\begin{array}{r} 397\cdot 04 \\ 296\cdot 407 \\ \hline 100\cdot 633 \end{array}$$

100·633.—Answer.

MULTIPLICATION OF DECIMALS.

Rule.—Place the multiplier under the multiplicand as in simple multiplication and proceed in the same way. Point off in the product as many figures as there are decimals in the multiplier and multiplicand, beginning to count their number from right to left.

Multiply 67·04 by ·05.

$$\begin{array}{r} 67{\cdot}04 \\ {\cdot}05 \\ \hline 3{\cdot}3520. \end{array}$$—Answer.

There are two decimals in multiplier and two in the multiplicand, therefore four are pointed off.

Multiply 6·327 by 4·96.

$$\begin{array}{r} 6{\cdot}327 \\ 4{\cdot}96 \\ \hline 37962 \\ 56943 \\ 25308 \\ \hline 31{\cdot}38192. \end{array}$$—Answer.

Multiply ·1 by ·1.

$$\begin{array}{r} {\cdot}1 \\ {\cdot}1 \\ \hline {\cdot}01 \end{array}$$

In the Rule, instructions are given to point off as many figures in the product as there are decimals in the multiplier and multiplicand; therefore, there is one in each, and there must be two in the product:—

this is done by annexing a cypher to the left of the figure in the product, and the point is placed to the left of the cypher.

Any number of decimals when multiplied together and their product has less figures then there are in the multiplier and multiplicand, then cyphers has to be annexed to the left as shown above to make up the proper number.

Multiply ·3 by ·3.

·3
·3
——
·09.—Answer.

Multiply ·12 by ·12.

·12
·12
——
·0144.—Answer.

To multiply any sum by $\dot{3}$, the product will be the same as if the sum was divided by 3. To multiply any sum by $\dot{6}$ will be same as ⅔ of that sum. To multiply any sum by ·125 will be the same if three cyphers was annexed to the right of it, and then divided by 8. To multiply any sum by ·5 will be the same as to divide the sum by 2. To multiply any sum by ·25 will be the same if two cyphers was annexed to the right of it, and divided by 4. To multiply any sum by ·9999 will be the same if four cyphers was annexed to the right of it, and then the multiplicand subtracted from it.

Multiply 1278 by 9999.

1278	12780000
9999	1278
11502	12778722.—Answer.
11502	

[OVER.]

```
 11502
11502
-----------
12778722.- Answer.
```

Multiply ·001 by ·001.

```
   ·001
   ·001
 -------
·000001
```

Multiply ·1 by ·5.

```
 ·1
 ·5
 --
·05
```

A Coal Bunker is 38 feet 4 inches long, by 22 feet 4 inches broad, and 10 feet 8 inches deep; find the quantity of coals it will contain at 42 cubic feet per ton.

$38\ 4 \times 22\ 4 \times 10\ 8 = 38{\cdot}333\dot{3} \times 22{\cdot}333\dot{3} \times 10{\cdot}666\dot{6} = 217{\cdot}425$

```
                  38·33̇3         38·33333
                  22·333         33333·22
                 -------        ---------
                 115000          7666666
                115000            766666
               115000             115000
               76666               11500
              76666                 1150
             ----------              115
             856·091                  12
              10·666            ---------
            ---------           856·1111
            5136546             66666·01
           5136546              ---------
          5136546                8561111
         8560910                  513666
42÷=6×7  -----------               51366
       6)9131·066606                5136
       -------------                 513
       7)1521·844434                  56
       -------------            ---------
         217·406347          42)9131·851
                               ----------
                              217·425.— Answer.
```

Or by vulgar fractions.

$38\frac{1}{3} \times 22\frac{1}{3} \times 10\frac{2}{3} = 217$ 8 cwt. 2 qrs.

```
   3     3     3
 ---   ---   ---
 115    67    32
```

then $\frac{115}{3} \times \frac{67}{3} \times \frac{32}{3}$

```
                       115
                        67
                     -----
                       805
                      690
                     -----
                      7705
                        32
                    ------
                     15410
                    23115
                   -------
3 × 3 = 9+         9)246560
                   ----------
                   3)27395·555
                   -----------
42+ = 6 × 7        6)9131·851
                   -----------
                   7)1521·975
                   -----------
                     217·425
                         ·20
                   -----------
                       8·500
                           4
                       -----
                       2·000
```

This sum has to be worked out by decimals in passing an examination by the board of trade—it is easier to work it out by vulgar fractions than by decimals.

From the various ways of working out this sum, it is evident that to reduce the dimentions of the bunkers to improper fractions, is the easiest, the simplest, and equally correct.

Multiply ·005 by ·005

```
   ·005
   ·005
 ───────
.000025
```

.000025 = to $\frac{25}{1000000}$ = $\frac{1}{40000}$ part of one.

Multiply ·345 by ·125.

```
   ·345
   ·125
   ────
   1725
   690
  345
 ──────
 ·043125
```

or $8)\cdot\frac{345000}{043125}$ the three cyphers annexed, the reason is plain, for $\frac{1}{8}$ gives the decimal of ·125.

DIVISION OF DECIMALS.

Rule.—Divide as in simple division, and point off in the quotient as many figures for decimals—as the decimal figures in the dividend exceed those of the divisor. The reason for this is plain, for if the quotient multiplied by the divisor, give the amount of the dividend, then the dividend must have as many decimal figures as the divisor and quotient put together. If the divisor has two decimals, and the divident four, then the quotient will have two; but if the divisor and dividend have the same number of decimals, then their will not be any in the quotient, unless

cyphers are annexed if there is a remainder of the dividend which often happens, and in this case there will be a decimal for every cypher annexed.

Or if there are more decimals in the divisor than in the dividend, then annex cyphers until they are equal, and the quotient will be a whole number.

Divide 27·32 by 27·12.

```
27·12)27·32(1·00737
      27 12
      -----
        20000
        18984
        -----
         10160
          8136
         -----
          20240
          18984
          -----
           1256
```

Divide 3475·48 by 2·54.

```
2·54)3475·48(1368·3 nearly.
     254
     ---
      935
      762
      ---
       1734
       1524
       ----
        2108
        2032
        ----
          760
          762
```

As the decimals in the divisor and dividend are equal, there is not any in the quotient unless cypher is annexed.

Divide 38976 by 48·92.

48·92)38976·00(796·72
34244
47320
44028
32920
29352
35680
34244
14360
9784
4576

Cyphers are annexed to the dividend to make it equal with the divisor.

Divide 7854·33 by ·125.

·125)7854·333(62834·$\frac{83}{125}$
750
354
250
1043
1000
433
375
583
500
830

There are three decimals in the divisor, and one is annexed to the dividend, the figure is a repeater, therefore three is annexed.

Divide 897·652 by 10.

10)897·652
89·7652

The working of this sum is to show that it only requires the point moved one figure from right to left, as shown in the example, and for 100, two figures, &c.

Divide ·01 by ·01.

$$\begin{array}{r} \cdot01)\cdot01 \\ \hline 1 \end{array}$$

If we turn over to multiplication of fractions, the product of this sum is ·0001 equal to a tenth thousand part, but by division it is a whole number.

Divide ·1 by ·1.

$$\begin{array}{r} \cdot1)\cdot1 \\ \hline 1 \end{array}$$

This gives a similar result to the above, but in multiplication the product is $\frac{1}{100}$ part.

Divide 61 by 79000.

$$\begin{array}{l} 79\cdot000)\cdot0610(\cdot000772\frac{12}{79}.\text{—Answer.} \\ \qquad\quad 553 \\ \qquad\quad \overline{\ \ 570} \\ \qquad\quad\ \ 553 \\ \qquad\quad \overline{\quad 170} \\ \qquad\qquad 158 \\ \qquad\quad \overline{\qquad 12} \end{array}$$

Or by the contracted way

$$\begin{array}{l} 79\cdot00)\cdot06100(\cdot000772\frac{12}{97}. \\ \qquad\qquad\quad 570 \\ \qquad\qquad\quad 170 \\ \qquad\qquad\quad\ \ 12 \end{array}$$

In the contracted way, the remainder is put down only, but we think there is a liability to make mistakes.

Divide 2508·92806 by 92·41035 so as to have four decimals in the quotient.

Contracted way.	Common way.
92·4103,5)2508·928,06(27·1498	92·4103,5)2508·928,06(27·1498
1848 207	1848 207 0
660721	66072106
646872	64687245
13849	13848610
9241	9241035
4608	46075750
3696	36964140
912	91116100
832	83169315
80	79467850
74	73928280
6	5539570

It will be observed that by the contracted way there is less labour, but it requires practice to work this correct.

The above sum is worked out in Hutten's Mathematics, by puting down the remainder only, which is less figures than the above.

EXTRACTION OF THE SQUARE OR SECOND ROOT.

To extract the square or Second Root of any given number.

First.—Point off in figures of two places, beginning at units with the first point, hundreds for the second point, ten thousands for the third point, and so on over every second figure, beginning at the right hand and pointing off to the left hand in whole numbers, but pointing to the left in decimals.

Second.—Find the greatest square number in the first point on the left hand, placing its root in the quotient to the right of the number, and also to the left as a divisor in division.

Third.—Multiply this figure by itself and place the product under the first point; subtract and to the remainder bring down the next point for a dividend.

Fourth.—Double the figure set in the divisor; find how often it is contained in the dividend (preserving always the unit's place), set that figure found in the quotient and also in the unit's place of the divisor.

Fifth.—Multiply this divisor by the last figure in the quotient, and subtract the product from the dividend, and to the remainder bring down the next point for a new dividend, double the last figure set in the divisor and proceed as before to the last period.

Extract the square root of 30976.

```
   1 |30976(176 square root.—Answer.
   1 |1
  ---|----
  27 |209
   7 |189
  ---|-----
 346 | 2076
     | 2076
     | ....
```

Squares 1 4 9 16 25 36 49 64 81.
Roots 1 2 3 4 5 6 7 8 9.

Extract the square root of 100.

```
 1 |100(10 square root.—Answer.
   |1
   |--
   |·00
```

What is the square root of 622521.

```
    7 |622521(789 square root.—Answer.
    7 |49
  ----|----
  148 |1325
    8 |1184
  ----|-----
 1569 | 14121
      | 14121
```

What is the square root of 4795·25731.

```
 6    |4795·25731(69·247 square root.—Ans.
 6    |36
 -----|----
 129  |1195
   9  |1161
 -----|-----
 1382 |  3425
    2 |  2764
 -----|-------
```

13844	66173
4	55376
138487	1079710
	969409
	110301

What is the square root of 24674·1264.

1	24674·1264(157·08
1	1
25	146
5	125
307	2174
7	2149
31408	251264
	251264

What is the square root of $\frac{169}{1369}$.

1	169(13	3	1369(37
1	1	3	9
23	69	67	469
	69		469

New numerator 13 13

$$\frac{13}{37}=\frac{13}{37}.\text{—Answer.}$$

New denominator 37 37

What is the square root of $\frac{64}{81}=\frac{8}{9}$.

EXTRACTION OF THE CUBE OR THIRD ROOT.

To find the Cube or Third Root of any given number; proceed as has been shown in the square root, by pointing off the given number into periods: but instead of two figures as in the square root, point them off in three figures, namely:—first point over units, second over thousands, and so on from right to left in whole numbers, and to the right in decimals.

Second.—The reason why two figures are pointed off for the square root, three for the cube root, four for the fourth root, and so on is namely:—that the square of a single figure never consists of more than two figures, the cube never more than three figures, the fourth root more than four figures and so on.

Find the greatest cube contained in the first period on the left; set its root in the quotient, also its square placed to the left of the given number: cube this figure placed in the quotient and place its product under the first period, subtract and to the remainder bring down the next period for a dividend.

Example 1st.—

Extract the cube or third root of 312908547069.

	6×6=36	312908547069(6789
		216
6×3=18×6=	10800	
187×7=	1309	96908
7×2=14	12109	84763
201×67=	1346700	12145547
2018×8=	16144	
8×2 16	1362844	10902752
2034×678=	137905200	1242795069
20349×9=	183141	
	138088341	1242795069.

In Example 1st, the numbers in the first period are 312, and the nearest cube root of this sum is 6, therefore the square of 6 is placed to the left for a divisior, and when multiplied by 6 gives the cube, namely, 216. This sum subtracted from 312 leaves a remainder of 96, to this remainder annex the next period for a new dividend which is 96908; to find a divisor for this sum, place the figure found for the quotient, namely, 6, to the left to be multiplied for a divisor as shown in the example. Multiply this 6 by 3 and then by 6, thus 6×3×6=108 annex two cyphers which will be 10800, this sum is used as a trial divisor. See how many times 10800 is contained in 96908, leaving a margin for addition to be made to the divisor afterwards, 7 is the number of times, then 7 is placed in the quotient and also annexed to the right of 18 which will be 187, this sum is multiplied by the last figure in the quotient, thus 187×7=1309, this sum added to 10800 gives 12109, and this sum multiplied by the last figure in

the quotient is $12109 \times 7 = 84763$, this sum subtracted from the dividend gives a remainder of 12145, annex the next period for a new dividend which is 12145547. To find a new divisor for this sum, multiply the last figure found in the quotient by 2 which is $7 \times 2 = 14$, add this sum to 187 which gives 201, and 201 multiplied by the figures in the quotient 67 gives 13467, then annex two cyphers, thus 1346700: this sum is a trial divisor. The number of times 1346700 are contained in 12145547 are 8 times, then put the figure 8 in the quotient and also to the right of 201 which makes it 2018, and this sum multiplied by 8 gives 16144; this sum added to 1346700 gives 1362844, and 1362844×8 the last figure found in the quotient gives 109022752 which is subtracted from the dividend leaves a remainder of 1242795, annex the next period for a new dividend which is 1242795069; to find a new divisor for this sum, multiply the last figure found in the quotient by 2 which are $8 \times 2 = 16$, add this sum to 2018 which gives 2034, this sum multiplied by the figures in the quotient 678 gives 137905200 with the two cyphers; this is a trial divisor. The number of times this sum is contained in 1242795069 are 9 times, then place this figure in the quotient and also to the right of 2034 which gives 20349, and this sum multiplied by 9 gives 183141, this sum is added to 137905200 gives 138088341, and this multiplied by 9 the last figure in the quotient gives 1242795069, leave no remainder.

Extract the cube root of 484476471864.

7×7	49	484476471864(7854 cube [root.—Answer.
		343
7×3=21×7	14700	
218×8=	1744	141476
8×2 = 16	16444	131552
234×78=	1825200	9924471
2345×5=	11725	
5×2 10	1836925	9184625
2355×785=	184867500	739846864
23554×4=	94216	
	184961716	739846864

If 7854 is multiplied three times by itself, it will give the sum 484476471864 as above

Extract the cube root of 92·959677.

4×4=	16	92·959677(4·53
		64
4×3=12×4=	4800	
125×5=	625	28959
5×2= 10	5425	27125
135×45 =	607500	1834677
1353×3 =	4059	
	611559	1834677

Decimals are pointed off from left to right according to rule.

Cube 4678, and then extract the root of that cube.

```
 4678
 4678
 ----
37424
32746
```

[OVER.]

28068
18712
21883684
4678
175069472
153185788
131302104
87534736

$4 \times 4 =$		16	102371873752 (4678
			64
$4 \times 3 = 12 \times 4 =$		4800	38371
$126 \times 6 =$		756	
$6 \times 2 =$	12	5556	33336
$138 \times 46 =$		634800	5035873
$1387 \times 7 =$		9709	
$7 \times 2 =$	14	644509	4511563
$1401 \times 467 =$		65426700	524310752
$14018 \times 8 =$		112144	524310752
		65538844	....

We have this method for the extraction of the Cube Root, from the work of Dr. Colenso, with slight alteration.

EXTRACTION OF THE FOURTH ROOT.

To find the Fourth Root of any given number: extract the square root two times as follows.

Find the Fourth Root of 622521.

```
   7 | 622521                         789(28·089 Fourth Root.
   7 | 49                           2 | 4
  ---|-----                         2 |---
 148 | 1325                        ---| 389
   8 | 1184                         48| 384
 ----|------                         8|-----
1569 | 14121                      ----| 50000
     | 14121                      5608|
                                     8| 44864
                                 -----|------
                                 56169| 513600
                                      | 505521
                                      |-------
                                      |   8079
```

Find the Fourth Root of 24674·1264.

```
    1 | 24674·1264(157·08, Second Root.
    1 | 1
  ----|-----------                 1 | 157·08(12·53, Fourth
   25 | 146                        1 | 1                    [Root.
    5 | 125                       ---|------
  ----|-----------                22 | 57
  307 | 2174                       2 | 44
    7 | 2149                     ----|-----
  ----|-----------               245 | 1308
31408 | 251264                     5 | 1225
      | 251264                  -----|------
      |-------                  2503 | 8300
                                     | 7509
                                     |-----
                                     |  791
```

EXTRACTION OF THE FIFTH ROOT.

To find the Fifth Root of any given number: assume the fifth power of a root approximate to the given number then say as three times the assumed power and twice the given number is to the difference between the given number and the assumed power, so is the assumed root to the difference between the true and assumed root, which difference to be added or subtracted as required.

Find the Fifth Root of 35322·184319.

The root of this number appears to be between 8·1 and 8·2, taking 8·1 for the assumed root; its fifth power is 34867·84401.

Then

3 × 34867·84401 plus 2 × 35322·184319 = 175247·900668.

```
      3                        2
 ————————————           ————————————
 104603·53203            70644·368638
  70644·368638
 ————————————          and 35322·184319—34867·84401
 175247·900668              34867·84401
                           ————————————
                             454·340309 difference.
```

Then as 175247·900668 : 454·340309 : : 8·1 : 8·121.

```
                           8·1
                      ————————————
                       454·340309
                     36347 22472
                     ————————————
175247·900668)3680·15650290(·021 × 8·1=8·121
              3504 95801336
              ————————————
               175 198489540
               175 247900668
```

EXTRACTION OF THE SIXTH ROOT.

When two or more powers are multiplied together, their product will be equal to the power of their roots added together, thus the multiplication of the second and third power together will give a product equal to the fifth power; but while the addition of the roots agree with the multiplication of the power of these roots together, the extraction of the root of any given number and then the extraction of that root found, will give a root equal to the product of the two roots multiplied together, therefore the second and third roots multiplied together are 2 × 3=6th root.

Find the sixth root of 98867482624, the 6th root is 68.

	4 × 4=	16	98867482624 (4624 the
			64 [cube or 3rd root.
4 × 3=	12 × 4=	4800	34867
	126 × 6	756	
6 × 2=	12	5556	33336
	138 × 46=	634800	1531482
	1382 × 2=	2764	
2 × 2 ×	4	637564	1275128
	1386 × 462=	64033200	256354624
	13864 × 4=	55456	
		64088656	256354624
			....

[OVER.]

6	4624(68 the sixth root.
6	36
128	1024
	1024

To extract the second or square root three times in any given number: the root found will be the eighth root.

To extract the cube or third root twice of any given number the root so found will be the ninth root.

The method for finding the fifth root is applicable for the finding any other root.

Table of the first nine powers of numbers.

1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.
1	1	1	1	1	1	1	1	1
2	4	8	16	32	64	128	256	512
3	9	27	81	243	729	2187	6561	19683
4	16	64	256	1024	4096	16384	65536	262144
5	25	125	625	3125	15625	78125	390625	1953125
6	36	216	1296	7776	46656	279936	1679616	10077696
7	49	343	2401	16807	117649	823543	5764801	40353607
8	64	512	4096	32768	262144	2097152	16777216	134217728
9	81	729	6561	59049	531441	4782969	43046721	387420489

NOTATION.

9 TRILLIONS.
8 Hundred Thousands of Billions.
7 Ten Thousand of Billions.
6 Thousands of Billions.
5 Hundreds of Billions.
4 Tens of Billions.
3 BILLIONS.
2 Hundred Thousands of Millions.
1 Ten Thousands of Millions.
0 Thousands of Millions.
9 Hundreds of Millions.
8 Tens of Millions.
7 MILLIONS.
6 Hundreds of Thousands.
5 Tens of Thousands.
4 Thousands.
3 Hundreds.
2 Tens.
1 Units.

If a larger number is required, then follow in order, Quadrillions, Quintillions, Sixtillions, Septillions, Octillions, Nonillions, Decillions.

TIME.

The division of time into years and months was enacted by Julius Cæsar, (called the old style), and was observed in Europe for nearly 16 centuries ; the length of the year was 365 days 6 hours, the 6 hours in four year's being equal to 1 day . after so long a trial it was found incorrect, and it was enacted or corrected by Pope Gregory, in the year 1582, to 365 days 5 hours 48 minutes and 49 seconds, which is the exact length of the year as marked by the seasons. It is evident that 5 hours 48 minutes and 49 seconds, multiplied by 4, will not be equal to 24 hours ; to correct this, the year's 1700, 1800, 1900, are not leap years, neither is 2100, 2300, 2500 and so on.

QUESTIONS FOR A SECOND ENGINEER.

The following sums to be worked out by an Engineer while passing his examination for a certificate of competency of the second class.

First.—Express the following in figures :—

Write down three million, six hundred and thirty-five thousand and four?

3,635,004.—**Answer.**

Second.—Add together as under.

	tons	cwt.	qrs.	lbs.
	8	13	3	23
	12	13	1	19
	7	12	2	22
	5	14	3	14
Tons ...	34	14	3	22.—Answer.

Third.—What is the product of 534 multiplied by 423?

```
   534
   423
  ----
  1602
 1068
2136
------
225882.—Answer.
```

Fourth.—Divide 225882 by 324.

```
324)225882(697⅙.—Answer.
    1944
    ----
     3148
     2916
     ----
      2322
      2268
      ----
        54
```

$$\frac{54}{324}=\frac{1}{6}.$$

Fifth.—The quantity of Coals on board are 179 tons, 16 cwt, 3 qrs., and 12 lbs. In 9 days there was consumed 160 tons, 13 cwt, 2 qrs., and 26 lbs. Find the quantity remaining?

tons	cwt.	qrs.	lbs.
179	16	3	12
160	13	2	26
19	3	0	14.—Answer.

Sixth.—A Coal Bunker is 38-feet 4-inches long, 22-feet 4-inches broad and 10-feet 8-inches deep. Find the quantity of Coal it will contain at the rate of 42 cubic feet per ton?

This sum to be worked out by decimals.

$$38\ 4 \times 22\ 4 \times 10\ 8 = \frac{38{\cdot}333\frac{1}{3} \times 22{\cdot}333\frac{1}{3} \times 10{\cdot}666\frac{2}{3}}{42} = 217{\cdot}425$$

[or 217 tons 8 cwt. 2 qrs.

Example 1st.—

```
      38·33333
   33333·22
   ---------
    7666666
     766666
     115000
      11500
       1150
        115
         12
   ---------
    856·1111
   66666·01
   ---------
    85611 11
     5136 66
      513 66
       51 36
        5 13
          56
   ---------
42)9131·851
   ---------
     217·425
```

Example 2nd.—

```
              38·33
              22·33
              -----
              11500
             11500
             7666
            7666
            -------
             855·91
              10·66
            -------
             513546
            513546
           85591
           --------
÷42=7×6  6)9124·0006
           ---------
         7)1520·6667
           ---------
            217·2381
```

Example 3rd.—

```
 115
  67
----
 805
690
----
7705
```

Or by Vulgar Fractions.

$$38\frac{1}{3} \times 22\frac{1}{3} \times 10\frac{2}{3}$$

$$\frac{115}{3} \times \frac{67}{3} \times \frac{32}{3},$$

[OVER.]

```
                      32
                    -----
                    15410
                   23115
3 x 3 x 3 = 27     -------
                 3)246560
                  ---------
÷ 27 = 3 x 9     9)82186·666
                  ----------
÷ 42 = 6 x 7      6)9131·851
                  ----------
                  7)1521·975
                  ----------
                     217·425
                          20
                  -----------
                       8·500
                           4
                    --------
                       2·000
```

The three examples in working out the above sum, two of them by decimals and one by vulgar fraction; in reducing the whole numbers to thirds, and then dividing by 27 which is equal to $3 \times 3 \times 3$.

Or by the contracted way, by inverting the multiplier the second example is not so correct, unless with much labour in working with a large number of decimal figures.

Seventh.—The consumption of coals per day to produce a speed of 14 knots per hour is $11\frac{1}{4}$ tons. What will be the consumption on a voyage of 1,200 miles?

```
 14 knots per hour.
 24 knots per day.
---
 56
28
---
336 knots per day.
```

[OVER.]

Then as

$336\frac{1}{4})1200 : : 11\frac{1}{4} : 40{\cdot}178 = 40$ tons 3 cwt. 2 qrs. 6 lbs.

$$\begin{array}{r}
11\frac{1}{4} \\
\hline
13200 \\
300 \\
\hline
336)13500(40{\cdot}178.\text{—Ans.} \\
1344 \\
\hline
600 \\
336 \\
\hline
2640 \\
2352 \\
\hline
2880 \\
2682 \\
\hline
\end{array}$$

Or by abreviation of terms

$$\begin{array}{r}
\text{as } \overset{}{\cancel{336}} : \cancel{1200} : : 11\frac{1}{4} : \overset{\text{tons}}{40{\cdot}178} \\
21 \quad \frac{1}{4})75 \\
11\frac{1}{4} \\
\hline
825 \\
18{\cdot}75 \\
\hline
\div 21 = 3 \times 7 \quad 7)843{\cdot}75 \\
\hline
3)120{\cdot}535 \\
\hline
40{\cdot}178.\text{—Ans.}
\end{array}$$

Or as $\cancel{336} : \cancel{1200} : : 11\frac{1}{4} : 40{\cdot}178.$

$$\begin{array}{r}
7 \quad \frac{1}{4})25 \\
11\frac{1}{4} \\
\hline
275 \\
6{\cdot}25 \\
\hline
7)281{\cdot}25 \\
\hline
40{\cdot}178
\end{array}$$

The first and second terms are abreviated by 48, that is divided by 48, which gives 7 for the first term and 25 for the second.

Eighth.—If the pressure of the steam on the piston is 21 lbs. above the Atmosphere, and the Barometer on the condenser shows 28-inches of mercury, what is the effective pressure on the piston?

Thirty inches of mercury are equal to a pressure of $14{\cdot}7\frac{59}{120}$ lb., but in daily practice it is taken at 15 lbs.,

or what is the same thing, 2-inches of mercury to 1 lb. pressure.

Pressure of steam=21 lbs.

Pressure from vacuum 28÷2 = 35 lbs.—Answer.

Ninth.—What pressure of steam will be required to blow off the brine through the blow off cock, the bottom of the boiler being 18-feet below the level of the sea, allowing 2·305 feet to be equal to 1 lb.

As 2·305 : 18 : : 1 : 7·8 lbs.—Answer.

```
        1
     ------
2·305)18·000(7·8
      16 135
     ------
       18650
       18440
       -----
         210
```

There are three cyphers annexed to the dividend, to be equal to the divisor.

Tenth.—How many revolutions must an Engine make to drive a paddle 12½ knots per hour, the diameter of the wheel being 20¼-feet and the knot 6080-feet.

$$\frac{12\frac{1}{2} \times 6080}{20\frac{1}{4} \times 3{\cdot}1416} = 1194{\cdot}64 \text{ revolutions.—Answer.}$$

```
3·1416        ½)6080
   20¼           12½
-------       -------
628320         72960
  7854          3040
-------       -----------
636174         )76000·0000(1194·64.—Answer.
                636174
               -------
               1238260
                636174
               -------
                6020860
                5725566
               -------
```

[OVER]

```
2952940
2544696
-------
 4082440
 3817044
 -------
  2653960
  2544696
  -------
```

Eleventh.—The pitch of a screw is 23-feet; How many revolutions must it make to advance $11\frac{1}{4}$ knots per hour?

$$\frac{11\frac{1}{4} \times 6080}{23} = 2973{\cdot}9 \text{ revolutions per hour.}$$

```
  6080
     11¼
 ------
 66880
  1520
 ------
23)68400(2973·9
   46
   --
   224
   207
   ---
    170
    161
    ---
     90
     69
     --
     210
     207
     ---
       3
```

Twelfth.—A safety valve is loaded to $16\frac{3}{4}$ lbs. by a direct weight of $155\frac{3}{4}$ lbs.; How many pounds must be taken off to reduce the pressure to $15\frac{1}{4}$ lbs. per square inch?

All questions of this kind may be worked out by the rule of three, as follows:—As the pressure per square inch on

the valve is to the direct weight, so is the difference between the original pressure and that to which it is to be reduced per square inch to the quantity to be taken off.

$16\frac{3}{4}$ original pressure.
$15\frac{1}{4}$ reduced pressure.

$1\frac{1}{2}$ difference.

Then as $16\frac{3}{4} : 155\frac{3}{4} :: 1\frac{1}{2} : 13{\cdot}9477$ lbs. quantity to be [taken off.

$$\begin{array}{l} \ \ 4 \qquad 4 \\ \hline 67 \quad \tfrac{1}{2})623 \\ \qquad\quad 1\tfrac{1}{2} \\ \hline \qquad\quad 623 \\ \qquad\quad 311{\cdot}5 \\ \hline \qquad 67)934{\cdot}5 \\ \hline \qquad\quad 13{\cdot}9477 \text{ lbs.—Answer.} \end{array}$$

Thirteenth.—What height must a safety valve be lifted to be equal to the area of the valve: the valve is 9-inches diameter?

$$\frac{9 \times 9 \times {\cdot}7854}{9 \times 3{\cdot}1416} = 2\tfrac{1}{4}\text{-inches.—Answer.}$$

The Answers to all sums of this kind is one fourth of the diameter, ·7854 is one fourth of 3·1416, and to multiply by 9 and then divide by 9 would not alter the height, then there is the diameter left to be divided by 4 as follows.

$$\frac{9 \times \overset{1}{\cancel{9}} \times \overset{1}{\cancel{{\cdot}7854}}}{\underset{1}{\cancel{9}} \times \underset{4}{\cancel{3{\cdot}1416}}}$$

$$\begin{array}{l} 4)9 \\ \hline \ \ 2\tfrac{1}{4}\text{.—Answer.} \end{array}$$

How many cubic feet of water will be extracted in an hour, by a brine pump $3\frac{3}{4}$-inches diameter, the length of the stroke 14-inches, and making 21 strokes per minute, the pump being $\frac{5}{8}$ full each stroke?

$$\frac{3·75 \times 3·75 \times ·7854 \times 14 \times 21 \times 5 \times 60}{12 \times 12 \quad \times 12 \quad \times 8} = 70·4674 \text{ cubic feet.}$$

[—Answer.

Or by abreviation and fractions.

$$\frac{\overset{5}{\cancel{15}} \times 15 \times \overset{·1309}{\cancel{·7854}} \times \overset{7}{\cancel{14}} \times 21 \times 5 \times \overset{5}{\cancel{60}}}{4 \times 4 \times \underset{4}{\cancel{12}} \times \underset{\cancel{2}}{\cancel{12}} \times \underset{1}{\cancel{12}} \times 8}$$

3·75
3·75
———
1875
2625
1125
———
14·0625
·7854
———
562500
703125
1125000
984375
———
$11·0446875\cancel{0}$
14
———
441787500
110446875
———
$154·625625\cancel{0}$
21
———
154625625
309251250
———
3247·138125
5
———
16235690625
60
———

·1309
15
———
6545
1309
———
1·9635
5
———
9·8175
7
———
68·7225
5
———
343·6125
21
———
3436125
6872250
———
7215·8625
5

[OVER.]

12)974141·437500	4)36079·3125
12)81178·453125	4)9019·828125
12)6764·871093	4)2254·957031
8)563·739257	8)563·739257
70·467407	70·467407

The advantage gained by abreviation or lessening the numbers, the one against the other, is that it is equally correct with less labour and therefore less liable to make mistakes; also it takes less time to work the sums out.

Fourteenth.—If a Bar of Iron 1-inch square be torn assunder by a force of 4500 lbs. What strain will it require to tear assunder a bar of iron 1¼-inch square?

As $1^2 : 1{\cdot}25^2 :: 4500 : 703{\cdot}125$ lbs.—Answer.

1·25	Or as $1^2 : (1\frac{1}{4})^2 :: \cancel{4500} : 7031{\cdot}25$
6 25	4 4 1125
250	25
125	4 5
1·5625	4 5 5625
4500	2250
7 812500	$\cancel{16}$ 25
62 500	4 4)28125
7031·2500.—Answer.	7031·25.

Fifteenth.—What is the Horse Power of an Engine, the diameter of the cylinder being 5-feet 6-inches; the length of the stroke 6-feet 3-inches; the revolutions 46, and the effective pressure per square on the piston 21¾ lbs?

5 6 $= \dfrac{66 \times 66 \times {\cdot}7854 \times 21{\cdot}75 \times 6{\cdot}25 \times 46 \times 2}{33000} = 1296{\cdot}558$ [horse power, nearly.

12

66

66
66

396
396

4356
·7854

17424
21780
34848
30492

3421·2024
21·75

171060120
239484168
34212024
68424048

74411·152200
6·25

3720557610
1488223044
4464669132

465069·701250
46

2790418207500
1860278805000

21393206·25750
2

33000)42786412·5150(1296·558 H. P.
33

[OVER.]

97
66
———
318
297
———
216
198
———
184
165
———
191
165
———
262
264

Or by abreviation as under.

$$\frac{\overset{1}{\cancel{66}}\times 66\times \cdot7854\times \overset{\cdot87}{\cancel{21\cdot75}}\times \overset{1\cdot25}{\cancel{6\cdot25}}\times \overset{23}{\cancel{46}}\times \overset{1}{\cancel{2}}}{\cancel{33000}}$$

$\cancel{500}$
$\cancel{100}$
$\cancel{20}$
$\cancel{10}$
$\cancel{5}$
1

·7854
66
———
47124
47124
———
51·8364
·87
———
3628548
4146912
———
1¼ + ¼)45·097668
11 274417
———
56·372085
23
———
169116255
112744170
———
1296·557955 H.P.

It does not require argument to show how much easier the sums are worked out by cancelling than by the routine of multiplying, and dividing by the sums without being reduced the one against the other. The divisor 33000 being totally cancelled so that there is not anything to divide by, and when multiplying by 1·25, one fourth is added to the multiplicand, so that to multiply by 1 is so much labour lost; it only requires a little practice to overcome any little difficulty in cancelling.

QUESTIONS FOR CHIEF ENGINEER.

Find the side of a square whose area is 2088·49.

```
  4 |2088·49(45·7.—Answer.
  4 |16
 ---|----
 85 | 488
  5 | 425
----|-----
907 |  6349
    |  6349
```

Some repairs of the Engines has occupied 8 men $3\frac{1}{2}$ weeks, and has cost £35 10s. for wages. Some large repairs are required which it is expected will occupy 11 men 3 weeks; how much will it cost to pay the men at the same rate of wages?

As

$\frac{1}{2})8+3\frac{1}{2} : 11\times3 :: 35\ 10 :$ £41 16s. $9\frac{1}{4}\frac{5}{7}$d.—Answer.

```
    3½           20
    --          ----
    24           710
     4            11
    --          -----
    28           7810
                    3
                -----
28÷=4×7       4)23430
              --------
              7)5857 6
              ---------
             20)836 9¼⁵⁄₇
              ---------
               41 16 9¼⁵⁄₇.
```

Or as

```
            £   s.
½)8 : 11 : :35  10
  3½   3        11
 ---  --   -------
  24  33   390  10
   4              3
  --       --------
  28      4)1171 10
28÷=4×7   ----------
          7)292 17 6
          -----------
            41 16 9¼⁵⁄₇.
```

Required the weight to be placed on a double beat valve, to be equal to a pressure of 20 lbs. per square inch; the diameter of the valves are $12\frac{3}{4}$-inches, and $11\frac{1}{2}$-inches, 8 lbs. to be deducted for the weight of the valve.

Rule.—Square the diameter of each valve, multiply the difference of their product by ·7854 and 20 lbs., deduct 8 lbs. for the weight of the valve, and the remainder will be the weight required, or add the two diameters together. multiply that sum by their difference; also by ·7854 and 20 lbs., deduct from the product the weight of the valve, and the remainder is the weight required.

$$12{\cdot}75 \times 12{\cdot}75 = 162{\cdot}5625 = 468{\cdot}14875 \text{ lbs.— Ans.}$$

$$11{\cdot}5 \times 11{\cdot}5 = 132{\cdot}25$$

12·75	30·3125
12·75	·7854
63 75	1212500
8925	1515625
15300	2425000
	2121875
1625625	
	23·80743750
11·5	20
11·5	
	476·14875~~000~~
57 5	8
1265	468·14875
13225	

Or by Rule 11.

$12\frac{3}{4}+11\frac{1}{2}=\frac{1}{4})24\frac{1}{4}$ the sum of the diameter.

$12\frac{3}{4}-11\frac{1}{2}=\quad 1\frac{1}{4}$ the difference.

$24\frac{4}{16}$

$6\frac{1}{16}$

[OVER.]

F

$$
\begin{array}{r}
30\frac{5}{16} \\
20 \\
\hline
606{\cdot}25 \\
7854 \\
\hline
242500 \\
303125 \\
485000 \\
424375 \\
\hline
476{\cdot}148750 \\
8\phantom{{\cdot}148750} \\
\hline
468{\cdot}14875.
\end{array}
$$

Required the weight to be placed at the end of a safety valve lever, to be equal to the pressure of 35 lbs. per square inch on the valve, the diameter of the valve being 3-inches, the distance from the centre of joint to the valve is $3\frac{1}{2}$-inches, and from the valve to weight 15-inches, the effective weight of the lever is 23 lbs , and the weight of the valve 7 lbs.

$$35 \times 3 \times 3{\cdot}7854 = 247{\cdot}4010 - 30 = \frac{217{\cdot}401 \times 3{\cdot}5}{18{\cdot}5} = \overset{\text{lbs.}}{41{\cdot}13} \text{ [nearly}$$

$$
\begin{array}{r}
3 \\
3 \\
\hline
9 \\
{\cdot}7854 \\
\hline
7{\cdot}0686 \\
35 \\
\hline
353430 \\
212058 \\
\hline
247{\cdot}4010 \\
23 + 7 = \quad 30\phantom{{\cdot}4010} \\
\hline
\end{array}
$$

Total pressure on the valve including the effective weight of lever and valve.

[OVER.]

```
                     217·401ø
                         3·5
                   ─────────
                    108 7005
                    652 203
                   ─────────
3·5+15=18·5       )760·9035(41·13
                   740
                   ───
                    209
                    185
                    ───
                     240
                     185
                     ───
                      553
                      555
```

The effective weight of the valve and lever must be deducted before being multiplied by the distance from the centre of joint of lever to the valve, namely, 3·5 inches, and divided by the whole length of the lever, namely, 18·5-inches. Had the distance from the centre of joint of lever been 3-inches instead of $3\frac{1}{2}$-inches, the answer would have been found by dividing 217·401 by 6, because the length of lever would have been 18-inches and $6 \times 3 = 18$.

A bar of iron marked off at distances of 3-inches, and balanced on the top of the valve spindle, exactly at one of these distances, and then place a weight on this bar, say 40 lbs.. at 3-inches distance from the centre of valve spindle; it will require a weight of 40 lbs. placed at the same distance from the centre of valve spindle on the other end of this bar to balance it, this would be equal to a direct weight of 80 lbs. on the valve (without the weight of the bar,) and if one of the weights is moved 3-inches farther, say 6-inches from the valve, it will

take 80 lbs. at the 3-inches distance on the other end to balance this bar, so that the direct weight is increased on the valve from 80 to 120 lbs., and if the weight is moved to 9-inches from the centre of valve, it will take 120 lbs. at the 3-inches distance on the other end of the bar, and so on for every 3-inches towards the end of the bar. From this explanation it will be evident that a lever on a valve takes as much weight from the end that it is fastened by a joint as are equal to the weight, and the distance that it is placed on the other end of the lever from the valve; the valve spindle acting as a heel to a lever.

What is the total pressure on the flat bottom of a boiler 9-feet 6-inches long, and 6-feet 8-inches broad, the pressure of steam is 30 lbs. per square inch, and the height of the water is 17-feet, also the number of stays $1\frac{1}{2}$-inch square, so that each square inch of section of the stay will bear the strain of 4500 lbs.

9 6×6 8
12 12
——— ———
114 ×80 =9120×30=273600 lbs. pressure by steam.
80 9120×17= 67262·47 lbs. pressure from [water.
——— ——— ———
9120 2·305. 340862·47—Total pressure.

9120
17
———
63840
9120
———
2·305)·55040·000(67262·47
·3830·
———

[OVER.]

```
        16740
        16135
        -----
          6050
          4610
          -----
          14400
          13830
          -----
            5700
            4610
            -----
            10900
             9220
            -----
             16800
             16135
```

$$\text{As } 1^2 : 1\tfrac{1}{2}^2 :: 4500 : 10125 \div 340862{\cdot}47 = 33{\cdot}665 \text{ stays.}$$

```
       2 2
    As 1:1½  :  :  4500 : 10125
       2 2            9
       ----        -----
       2 3       4)40500
       2 3        ------
       ----        10125
       4 9
                10125)340862·47(33·665 stays
                      30375
                      -----
                       37112
                       30375
                       -----
                        67374
                        60750
                        -----
                         66247
                         60750
                         -----
                          54970
                          50625
                          -----
                           4345
```

Required the heating surface of tubes and tube plates of a boiler, the diameter of the tubes are $2\frac{3}{4}$-inches, length 7-feet, and 220 in number, and the plates 8-feet 6-inches long and 7-feet broad.

By decimals $\frac{2\cdot75\times3\cdot1416\times220\times7}{12}=1108\cdot723$-ft. tubes.

$8\ 6=8\frac{1}{2}\times7\times2=119\cdot$

$\overline{1227\cdot723}$ feet.

End of tubes to be deducted.

$$\frac{2\cdot75\times2\cdot75\times\cdot7854\times220\times\overset{1}{\cancel{2}}}{\underset{6}{\cancel{12}}\times12}=18\cdot1487$$

1209·5743.-feet.—Total.

3·1416
2·75
———
157080
219912
62832
———
8·6394$\cancel{0}\cancel{0}$
7
———
60·4758
220
———
12095160
1209516
———
12)13304·6760
———
1108·723

2·75
2·75
———
1375
1925
550
———
7·5625
·7854
———
302500
378125
605000
529375
———
5·9395875$\cancel{0}$
220
———
1187917500
118791750
———
12)1306·7092500
———
6)108·8924375
———
18·1487395

$8\frac{1}{2}$
2
—
17
7
—
119

By vulgar fractions $2\frac{3}{4}$ is here reduced to an improper fraction $\frac{11}{4}$.

$$2\tfrac{3}{4} = \frac{11 \times 3 \cdot \overset{\cdot 7854}{\underset{}{\cancel{1416}}} \times \overset{110}{\cancel{220}} \times 7}{\cancel{4} \times \underset{6}{\cancel{12}}} = 1108 \cdot 723\text{-feet from tubes.}$$

$$8\tfrac{1}{2} \times 7 \times 2 = 119 \cdot \text{ feet from [plates.}$$

$$1227 \cdot 723$$

·1309	2
11	17
1·4399	7
110	119
158·3890	
7	
1108·7230	

$$\frac{11 \times 11 \times \overset{1309}{\cdot\cancel{7854}} \times \overset{110}{\cancel{220}} \times \overset{1}{\cancel{2}}}{4 \times 4 \times \underset{\underset{1}{\cancel{2}}}{\cancel{12}} \times \underset{\cancel{6}}{\cancel{12}}} = 18 \cdot 1487 \text{ end of tubes.}$$

$$1209 \cdot 5743$$

1309
11
———
1·4399
11
———
15·8389
110
———
4)1742·2790
———
4)435·56975
———
6)108·8924375
———
18·1487395

3·1416 is abreviated with the cancelling of 4 and 6, and 220 is divided by 2, and also 12 by 2.

Heating surface of tubes= 1108·723
Heating surface of tube plate 119—18·1487= 100·8513
1209·5743
End of tubes 18·1487.

The pitch of a screw propeller is 15-feet, and makes 50

revolutions per minute, what will be the progression of the propeller in knots per hour, and the rate of the ship, allowing 20 per cent. for slip, 6080-feet equal to a nautical mile or knot.

$$\frac{15 \times 50 \times 60}{6080} = 7{\cdot}4 \text{ miles progression of propeller.}$$

$$\frac{\overset{1}{\cancel{20}} \times 7{\cdot}4}{\underset{5}{\cancel{100}}} = \quad = \quad \begin{array}{l} 1{\cdot}48 \text{ slip.} \\ \hline 5{\cdot}92 \text{ rate of ship.} \end{array}$$

$$\begin{array}{r} 5)7{\cdot}4 \\ \hline 1{\cdot}48 \end{array} \qquad \begin{array}{r} 15 \\ 50 \\ \hline 750 \\ 60 \\ \hline 608{\cdot}0)4500{\cdot}0(7{\cdot}4 \\ 4256 \\ \hline 2440 \\ 2432 \\ \hline 8 \end{array}$$

Sea water contains $\frac{1}{32}$ of solid matter, and it requires that the water in the boiler should not contain more than $\frac{3}{32}$ of solid matter, what proportion will the quantity blown off be to the quantity evaporated.

Let A. B. and C. represent the water in a boiler at the density of $\frac{1}{32}$, each letter representing one third of the whole. Evaporate. A and B's quantity or $\frac{2}{3}$, and add the remaining solid matter to C will make C's quantity $\frac{3}{32}$, this quantity to be blown off, therefore A plus B is to C as 2 is to 1, or $\frac{1}{2}$ of evaporation.

Or suppose the boiler to contain 3 tons of water at the density of $\frac{1}{32}$, evaporate 2 tons, and add the remaining solid matter to the remaining ton will make it $\frac{3}{32}$, this quantity to be blown off, which is one half of the quantity evaporated.

To find the quantity by figures: let it be assumed that the boiler contains 10,000 gallons, and the density of the water in the boiler not to be more than $\frac{4}{32}$, which is 3 parts evaporated, and 1 blown off.

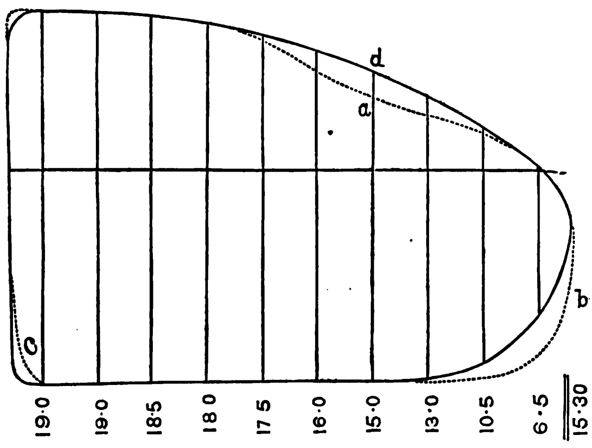
Then say as $3+1=4$: 10,000 : : 3 : 7500 gallons [evaporated

$$\begin{array}{r} 10{,}000 \\ 3 \\ \hline 4)30000 \\ \hline 7500 \end{array}$$

And as $3+1=4$: 10,000 : : 1 : 2500 gallons blown off.

$$\begin{array}{r} 10{,}000 \\ 1 \\ \hline 4)10000 \\ \hline 2500 \end{array}$$

Work out an indicator card, show the point where the steam is cut off, whether the slide valve is correct or not, or requires attention, and if the latter what?



The figure of this diagram shows that the slide is passing steam, this is shown by the line at *d*, which should have

been shown a curved line as at *a*, the eduction parts too contracted, the card should have had the figure as at *b*, the slide has not lead enough, the card should have shown as dotted at *c*.

The diameter of the cylinder is 3-feet 6-inches, stroke 5-feet, and making $20\frac{3}{4}$ revolutions per minute.

3-feet 6-inches equal to 42-inches.

$$\frac{42 \times 42 \times \cdot 7854 \times 15{\cdot}3 \times 5 \times 2 \times 83}{33000 \qquad\qquad 4} = 133{\cdot}28 \text{ H. P.}$$

$$\begin{array}{l}
20\frac{3}{4} \\
\underline{\quad 4} \\
83 \\
\overline{\quad 4}
\end{array}
\qquad
\begin{array}{r}
42 \\
\underline{42} \\
84 \\
\underline{168} \\
1764 \\
\underline{\cdot 7854} \\
7056 \\
8820 \\
14112 \\
\underline{12348} \\
1385{\cdot}4456 \\
\underline{15{\cdot}3} \\
41563368 \\
69272280 \\
\underline{13854456} \\
21197{\cdot}31768 \\
\underline{10} \\
211973{\cdot}17680 \\
\underline{83} \\
63591953040 \\
\underline{169578541440} \\
4)17593773{\cdot}67440 \\
\hline
\end{array}
\qquad 5 \times 2 = 10$$

33000)4398443·41860(133·28
33
109
99
108
99
94
66
284
264

Or by abreviation.

$$\frac{\overset{7}{\cancel{42}} \times \overset{21}{\cancel{42}} \times \overset{\cdot 3927}{\cancel{\cdot 7854}} \times 15\cdot 3 \times \cancel{5} \times \cancel{2} \times 83}{\underset{\underset{550}{\cancel{3300}}}{\cancel{33000}} \qquad \underset{\cancel{2}}{\cancel{4}}} = 133\cdot 28 \text{ H. P.}$$

·3927
7
2·7489
21
27489
54978
57·7269

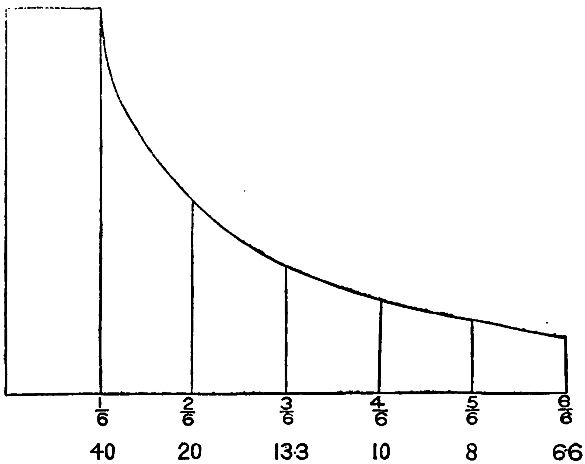
57·7269
15·3
1731807
2886345
577269
883·22157
83
264966471
706577256

÷550=5×110 5)73307·39031
11)1466·147806
133·28.

Steam is admitted into the cylinder at 25 lbs. pressure per square inch, above the pressure of the atmosphere, and it is cut off at $\frac{1}{6}$ of the stroke, required the mean pressure on the piston throughout the stroke, supposing the vacuum to be perfect.

The following method from Thomas Simpson, F.R.S., for finding the area of irregular curved surfaces.

To the sum of the extreme pressure per square inch, add four times the sum of the even pressures, and twice the sum of the odd pressures; this product divided by 3 will give the work done expansively on 1-inch of the piston.



The even numbers are 2 and 4; the odd numbers are 3 and 5; the last division the mean is taken, that is $6{\cdot}6+8=7{\cdot}3$.

Therefore the even numbers		20+10=30×4=120.
„ odd „		13·3+8=21·3×2=42·6.
And the mean of	...	8+6·6=7·3=7·3.
The extreme pressure	...	40 = 40.
		3)209·9
Work done expansively	... ...	69·96.
Then add the extreme pressure		40
Divide by 6 for the mean pressure		6)109·96
Mean pressure throughout the stroke		18·32.

How to set the eccentric of the link motion.

First.—Draw a line straight through the centre of the crank pin and crank shaft.

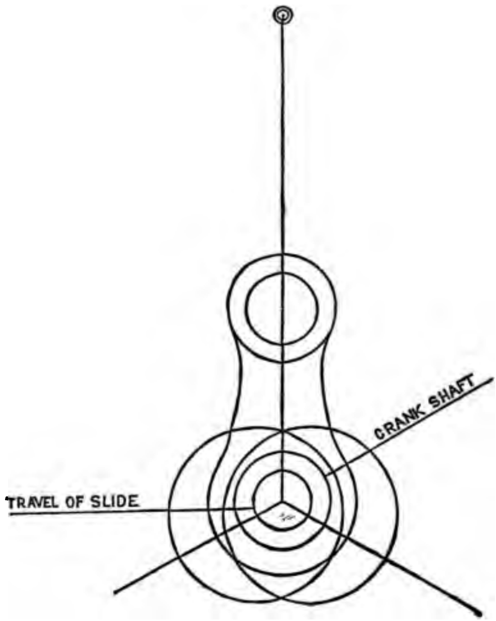
Second.—On this line mark off the lap and lead of slide from the centre of crank shaft, in an opposite direction of the throw

Third.—Scribe a circle equal in diameter to the travel of slide, using the centre of crank shaft for its centre.

Fourth.—Find the length of eccentric rod from centre of gab pin, to centre of crank shaft, add to this the lap and lead, take a pair of trammels this length, keep the end at gab pin stationary, and scribe on the end of crank shaft with the other end of trammels, and where this intersets the circle for travel of slide, is the centre of each eccentric, where it is to be keyed on the shaft.

If it is not convenient to apply the trammels as above described, it can be drawn out on a board, and the lines transferred to the crank shaft, keeping in mind the relative position of the eccentric rod to the throw of the shaft.

CENTRE OF GAB PIN.



SETTING OF SLIDE VALVE.

How to find the position for the eccentric, for an engine going one way with fixed eccentric.

First.—Find the length of eccentric rod by putting it in gear with the weigh shaft, and move the eccentric round on the crank shaft, so as to see that the slide travels equal distance over the ports top and bottom.

Second.—Place the engine on the centre (or full length of stroke,) set the slide with the necessary opening, (say from an eighth to one quarter of an inch as the case may require,) move the eccentric round until the gab falls in gear, this is placed where the eccentric is to be keyed on the shaft: care to be taken to see that the eccentric is in the right side of the crank. This will be found out by moving the engines round the way they are intended to be worked, and if right, the lead or opening of slide will be increased until it comes to full port; but if the eccentric is on the wrong side of crank, the slide will shut the opening given for lead, and open on the reverse side, if the former the eccentric has only to be keyed, but if the latter, it has to be moved round to the other side of the crank.

Where to fix the stops when only one eccentric is used, and the engine has to go backwards or forwards at will. Proceed as stated above by having the eccentric rod the right length, the engine placed exactly on its centre, and the slide with the necessary opening with the eccentric rod in gear, mark the shaft in that position for the first stop, then take the eccentric rod out of gear, move round the eccentric on the shaft to the other side until the gab

again drops in gear, this will give the position for the second stop: care to be taken not to move the engines.

When the slide is set, mark the slide rod to an iron gauge, so that at any time the position of the slide can be known.

ECCENTRIC EXPLAINED.

To find the throw of an eccentric pulley, if bored out, or on a turned shaft, measure from the shaft to the full side of the throw, and also the small side, subtract the lesser from the greater and the difference is the throw.

The crank doubles its throw when it revolves, that is to say a crank one foot of a throw, will give two feet stroke; but an eccentric whose difference is one foot, will have only one foot stroke.

How to find the length of gab lever if carried away.

Rule.—Divide the throw of eccentric by the travel of slide, and multiply the quotient by the valve lever, (both in inches,) and the product will be the length of gab lever in inches, the levers to be measured from centre to centre.

How to find the position of the gab and slide levers of the weighshaft.

Set the valve lever at right angles with the slide rod, when the slide is placed in the half of its travel.

The gab lever should be at right angles with a line stretched from centre of crank shaft to centre of pin for gab, when the lever for working the slide valve is at right angles with the slide rod, and the slide placed in the half of its travel.

QUESTIONS FOR PRACTICE.

(How to find the Circumference from the Diameter.)

How to find the circumference from the diameter.

The circumference of 1-inch diameter is 3·14159, &c., but in practice is taken at 3·1416-inches, and diameters are generally reckoned by this proportion to the circumference; sometimes as 7 : 22 : : 1-inch diameter to the circumference, or as 113 : 335 : : 1-inch diameter to the circumference: this last is the most correct proportion to find the circumference from the diameter, or to find the diameter from the circumference by reversing the terms thus, as 335 : 113 : : the circumference to the diameter.

What is the circumference of a circle whose diameter is 3-feet?

$3 \times 3{\cdot}1416 = 9{\cdot}4248$-feet, or 9-feet $5\frac{3}{32}$.—Ans.

$$\begin{array}{r} 3 \\ \hline 9{\cdot}4248 \\ 12 \\ \hline 5\ 0976 \\ 8 \\ \hline {\cdot}7608 \\ 4 \\ \hline 3{\cdot}0432 \end{array}$$

What length should a sheet of muntz metal $\frac{3}{8}$ of an inch thick, be cut, in its unbent state, to line an Air-pump 3-feet diameter?

In bending this plate of metal, the inside will crush and

the outside will draw or lengthen, therefore to find the length of this plate in its unbent state, the thickness of this plate must be subtracted from the diameter.

Then $3 - 0\frac{3}{8} = 2\ 11\frac{5}{8}$, or $2{\cdot}96875 \times 3{\cdot}1416 = 9{\cdot}3266$, or [9-feet $3\frac{7}{8}$-inches.

$$\begin{array}{r|l} 8 & 5\ {\cdot}0 \\ \hline 12 & 11{\cdot}625 \\ \hline & {\cdot}96875 \end{array}$$

$$\begin{array}{r} 2{\cdot}96875 \\ 3{\cdot}1416 \\ \hline 1781250 \\ 296875 \\ 1187500 \\ 296875 \\ 890625 \\ \hline 9{\cdot}326625\cancel{000} \\ 12 \\ \hline 3{\cdot}9195\cancel{00} \\ 8 \\ \hline 7{\cdot}3560 \end{array}$$

What length should a bar of iron $\frac{3}{4}$ of an inch thick be cut to hoop an Air-pump 3-feet diameter?

To this sum and all of the same kind, one thickness of the iron has to be added to diameter besides sufficient length for welding.

$3 + \frac{3}{4} = 3\frac{3}{4} \times 3{\cdot}1416$, or $3{\cdot}0625 \times 3{\cdot}1416 =$ 9-feet $7\frac{9}{16}$-inches.

$$\begin{array}{r|l} 4 & 3{\cdot}00 \\ \hline 12 & {\cdot}75 \\ \hline & {\cdot}0625 \end{array}$$

What length should a plate of muntz metal $\frac{1}{4}$ of an inch, be cut, in its unbent state, to line an Air-pump 4-feet 2-inches diameter?

4-feet 2-inches$-\frac{1}{4} = 4\ 1\frac{3}{4} = 49{\cdot}75$-inches.

$49{\cdot}75 \times 3{\cdot}1416 =$ 13-feet $0\frac{5}{16}$-inch.—Answer.

Find the diameter of a circle whose circumference is 156·2946-inches.

$$\frac{156·2946\text{-inches}}{3·1416}=49·75\text{-inches, or 4-feet } 1\tfrac{3}{4}\text{-inches.}$$

```
3·1416)156·2946(49·75÷12=4 1¾-inches.—Answer.
       125 664·
       --------
        306306
        282744
        -------
         235620
         219912
         -------
          157080
          157080
```

Or by Hoare's decimal system.

```
156·2946 × ·31831 = 49·75 [inches.
 ·31831
 -------
 1562946
 4688838
12503568
1562946
4688838
-----------
49·750134126
```

Find the diameter of a circle, whose circumference is 64·905456-feet.

$$\frac{64·905456}{3·1416}=20·66=20\text{-feet } 7\tfrac{9}{10}\text{-inches.—Answer.}$$

```
3·1416)64·905456(20·66-inches.—Answer,
       62 832··     12
       --------     ----
        207345      7·92
        188496
        -------
         188496
         188496
```

Find the diameter of a circle, whose circumference is 9·4248-feet.

```
9·4248 × ·31831 = 3 feet. --Answer.
·31831
-------
94248
```

[OVER.]

```
     94248
    282744
   753984
   94248
  282744
  -----------
  3·000008088
```

The diameter of a cylinder is 5-feet, find its area in square inches.

$5 \times 12 = 60 \times 60 \times {\cdot}7854 = 2827{\cdot}44$ square inches.

```
       60                        3600
       60                          11
     ----                       ------
     3600       14÷2 × 7=2)39600
    ·7854                       ------
    -----                      7)19800
    14400                       ------
   18000                        2828·57
  28800
 25200
 ---------
 2827·4400
```

A circular inch is $\frac{7854}{10000}$ part of a square inch, and if 3600 is multiplied by 7854, and divided by 10000, the Answer would be $2827\frac{4400}{10000}$; but this fraction is the same as expressed by decimals.

The fraction $\frac{7854}{10000}$ approaches very nearly $\frac{11}{14}$.

·7854 is half the diameter of an inch multiplied by half the circumference $= 1{\cdot}5708 \times {\cdot}5$.

HOW TO FIND THE AREA FROM THE DIAMETER.

Find the area of a ring in square inches, whose outside diameter is 20-feet 11-inches, and 3-inches broad.

3-inches on each side of the circle will make the inside diameter 6-inches less than the outside.

Therefore 20 11−6-inches = 20 5-inches the inside diameter.

```
ft. in.                     ft. in.
 20 5                        20 11
 12                          12
 ----                        ----
 245 × 245 = 60025           251 × 251 = 63001 — 60025
 245                         251               [=2976
 ----                        ----
 1225                         251
 980                         1255
490                          502
-----                        -----
60025                        63001
                             60025
                             -----
                              2976 circular inches.
                             ·7854
                             -----
                             11904
                            14880
                           23808
                          20832
                          ---------
                          2337·3504 square inches.
```

Or as under, add the two diameters together, and multiply that product by their difference.

20-ft. 11-in. + 20 5 = 41-ft. 4-in. = 2976 × 7854 = 2337·3504.

20-ft. 11-in.—20 5 = 6

The two diameters added equal 41-ft. 4-in.

And the difference equal 0-ft. 6-in.

```
ft. in.
 41 4
 12
 ----
496
  6
```

[OVER.]

```
  2976
 ·7854
------
 11904
14880
23808
20832
----------
2337·3504
```

This is the easiest and simplest.

What is the area (effective) of the piston of a trunk engine, the diameter of the piston is 75-inches, and the trunk 35-inches?

```
           75
           35
          ---
          110
75—35=     40
          ----
         4400
         ·7854
         -----
        17600
       22000
      35200
     30800
     ---------
     3455·7600
```

$75 + 35 = 110$

$75 - 35 = 40$

$110 \times 40 \times {\cdot}7854 = 3455{\cdot}76$ [effective area.—Ans.

Required the weight to be placed on a double beat valve, the weight to be equal to a pressure of 40 lbs. per square inch, the diameter of the valves are $10\frac{5}{8}$-inches and $9\frac{3}{8}$-inches?

$10\frac{5}{8} + 9\frac{3}{8} = 20$

$10\frac{5}{8} - 9\frac{3}{8} = 1\frac{1}{4}$

$20 \times 1\frac{1}{4} \times {\cdot}7854 = 19{\cdot}635 \times 40 = 785{\cdot}4$ lbs.—Answer.

NOMINAL HORSE POWER.

What is the Nominal Horse Power of a Trunk Engine, the trunk on one side only, the diameter of the cylinder is 75-inches and the trunk 35-inches, the crank 2-feet and makes 28 revolutions per minute, the effective pressure is 7-lbs. per square inch ?

75 × 75 × ·7854 = 4417·875 area of piston in square inches

75 + 35 = 110 × 40 × ·7854 3455·76 effective area on [trunk side.

2)7873·635

75—35 = 40 3936·8175 **mean area.**

$$\frac{3936\cdot8175 \times 7 \times 4 \times 2 \times 28}{33\,000} = 187 \text{ horse power.}$$

3936·8175
7
27557·7225
4 × 2 8
220461·78~~00~~
28
176369424
44092356
33000)6172929·84(187 horse power of one engine.
33 2
287 374 „ „ two engines.
264
232
231

Or by abreviation of terms.

$$\frac{\begin{array}{l}157{\cdot}4727\\ \cancel{787{\cdot}3635}\\ \cancel{3936{\cdot}8175}\times 7\times\cancel{4}\times\cancel{2}\times 28\end{array}}{\begin{array}{c}\cancel{33000}\\ \cancel{6600}\\ \cancel{1650}\\ \cancel{825}\\ 165\end{array}}$$

```
  157·4727
         7
  --------
 1102·3089
        28
  --------
 8818 4712
22046178
---------
165)30866·6492(187 horse power of one engine.
    165          2
    ----        ---
    1436        374  „  „  two engines.
    1320
    ----
     1166
     1155
     ----
       11
```

WHAT IS A HORSE POWER.

Messrs. Bolton and Watt suppose a Horse able to raise 33000 lbs. avoirdupois, 1-foot in a minute of time, or what is the same thing 1 lb raised 33000-feet per minute; 33000 lbs. raised one-foot per minute is admitted the standard of a commercial horse power, whether it is in buying, selling, settling disputes or efficiency.

The Nominal Horse Power is calculated at the effective pressure of 7 lbs. on the piston, with the supposed speed at which the piston is to travel, and the *real* or actual horse power is the effective pressure (as shown by the indicator,) and the speed at which the piston travels. Both the nominal and the actual horse power have the same divisor, namely, 33000 lbs. avoirdupois raised one foot per minute.

What is the horse power of an engine with trunk on one side of piston, the diameter of piston is 75-inches and the trunk 35-inches, the effective pressure of steam and vacuum is 27 lbs., the piston has 4-feet stroke and makes 34 revolutions per minute?

$75+35=110\times 40=4400$ circular inches top.

$75\times 75=$ 5625 circular inches bottom.

$$\frac{2)10025}{5012{\cdot}5}$$ mean circular inches.

$$\frac{5012{\cdot}5\times{\cdot}7854\times 27\times 34\times 4\times 2}{33{\cdot}000}=876{\cdot}1 \text{ one engine.}$$

5012·5
·7854

200500
250625
401000
350875

3936·81750
27

2755772250
787363500

106294·0725~~0~~
2 × 4 = 8

850352·58~~00~~
34

340141032
255105774

33000)28911987·72(876·1 horse power of one engine.
264 2

251 1752·2 „ „ two engines.
231

201
198

39
33

6

HORSE POWER AND THE HEIGHT OF A COLUMN OF WATER.

What will be the diameter of a Cylinder for an engine 200 nominal horse power, the effective pressure on the piston is 7 lbs. with 4-feet stroke, and making 25 strokes per minute?

To find the diameter of a cylinder from a given horse power, is the reverse of finding the horse power from a given diameter.

$$\frac{200 \times 33000}{4 \times 25 \times 2 \times 7 \times \cdot 7854} = 77 \cdot 47 \text{ diameter of cylinder.}$$

```
                33000
                  200
               ------
4×25×2=    200)6600000
             ---------
             7)33000·0000
             ------------                    [square inches
        ·7854)4714·2857(6002·4 area of cylinder in
              4712 4
              -------
                18857
                15708
                -----
                 31490
                 31416
                 -----

        7  |6002·4(77·47
        7  |49
      -----|----
      147  |1102
        7  |1029
      -----|----
```

1544	7340
4	6176
15487	116400
	108409

Or by abreviation as under.

$$\frac{\overset{5500}{\cancel{200} \times \cancel{33000}}}{\cancel{4} \times \cancel{25} \times \cancel{2} \times \cancel{7} \times \underset{\cdot 1309}{\cdot \cancel{7854}}}$$

7)5500·0000

·1309)785·7142(6002·4
7854

3142
2618

5240
5236

VERTICAL PRESSURE OF WATER.

Required the height of a column of water equal 15 lbs. pressure per square inch, a cubic foot of water at the temperature of 60° weighs $62\frac{1}{2}$ lbs., and this weight is equally divided over a surface of 144 square inches, therefore divide $62\frac{1}{2}$ lbs. by 144 and the quotient will be the pressure on a square inch at one-foot high, then say by proportion, as the pressure on a square inch is to 15 lbs., so is one-foot to 34·56-feet.

```
144)62·5(·434
    576
    ———
     490
     432
     ———
      580
      576
      ———
        4
```

$$\frac{62{\cdot}5}{144} = {\cdot}434 \text{ lbs.}$$

Then as ·434 : 15 : : 1 : 34·56-feet high.

```
            15
             1
          ————
·434)15·000(34·56
        1302
        ————
         1980
         1736
         ————
          2440
          2170
          ————
           2700
           2604
           ————
             96
```

This shows that it takes a column of water at the temperature of 60°, 34-ft, $6\frac{3}{4}$-inches high, to be equal to a pressure of 15 lbs. per square inch.

INCREASE OF SPEED AND CONSUMPTION OF FUEL.

A Screw is driven by wheel and pinion, the wheel is 14-feet diameter, and the pinion 7-feet diameter at the pitch line, and the speed of the pinion to the wheel is two to one; should new boilers call for wheel and pinion at a speed of three to one.

Find the diameter of wheel and pinion at the pitch line at this increased speed, without in any way altering the shafting.

Rule.—Double the distance between the centres of shafting, and also add the two required speeds together, then say as the two required speeds is to twice the distance between the centres of shafting, so is the large speed to the diameter of wheel, and by the same rule, so will be the small speed to the diameter of pinion.

Distance between centres of shafting $10\frac{1}{2}$-feet.

Then $10\frac{1}{2}+10\frac{1}{2}=21$-feet.

And the speeds $3+1=4$.

Therefore as $4 : 21 : : 3 : 15$-feet, 9-inches diameter of wheel.

$$\begin{array}{r} 21 \\ 3 \\ \hline 4)63 \\ \hline 15\ \ 9\text{-inches.} \end{array}$$

And as $4 : 21 : : 1 : 5$-feet 3-inches.

$$\begin{array}{r} 21 \\ 1 \\ \hline 4)21 \\ \hline 5\ \ 3 \end{array}$$

The two diameters must agree with the distance 21-feet.

Therefore 15 9+5 3=21-feet.

Or divide the distance between the centres of shafting by the speeds, the quotient will be the radius of pinion and subtract this radius of pinion from the distance between the centres of shafting, and the remainder will be the radius of wheel.

Thus 4)10·5 and 10·5—2·625= 7·875 radius of wheel.

2·625 radius of pinion.

It has been proved from experience, that the power expended on propelling a ship through the water, varies as the cube of the velocity, hence arises the great increase in the consumption of fuel, if the speed is increased from 10 to 12 miles per hour, or from 12 to 13 miles per hour.

If 35 tons of fuel per diem give a speed of 10 miles per hour, what will be the consumption if the speed is increased to 12 miles per hour?

$$
\begin{array}{rrll}
3 & 3 & & \\
\text{As } 10 : & 12 & : : & 35 \text{ tons.} \\
10 & 12 & & \\
\hline
100 & 144 & & \\
10 & 12 & & \\
\hline
1000 & 1728 & & \\
 & 35 & & \\
\hline
 & 8640 & & \\
 & 5184 & & \\
\hline
\end{array}
$$

$$
\begin{array}{r}
1000)60480(60{\cdot}48 \\
60000\phantom{(60{\cdot}48} \\
\hline
480\phantom{(60{\cdot}48}
\end{array}
$$

If 60 tons of fuel per day, gives a speed of 12 knots per hour, what will be the consumption per day, if the speed is increased to 13 knots per hour?

$$
\begin{array}{rcrl}
 3 & & 3 & \\
\text{As } 12 & : & 13 & :: \cancel{60} : 76{\cdot}28 \text{ tons.—Answer.} \\
 12 & & 13 & \;\;5 \\
\hline
 144 & & 39 & \\
 12 & & 13 & \\
\hline
 \cancel{1728} & & 169 & \\
 144 & & 13 & \\
\hline
 & & 507 & \\
 & & 169 & \\
\hline
 & & 2197 & \\
 & & 5 & \\
\hline
\div 144 = 12 \times 12 & & 12)10985 & \\
\hline
 & & 12)915{\cdot}416 & \\
\hline
 & & 76{\cdot}284 & \text{tons.—Answer.}
\end{array}
$$

35 tons per day, at 10 miles per hour equal 240 miles =6·85 miles per ton.

60 tons per day, at 12 miles per hour equal 288 miles =4·8 miles per ton.

76 tons per day, at 13 miles per hour equal 312 miles =4·1 miles per ton.

The increase from 12 to 13 miles give 24 miles per day, with an increased consumption of 16 tons, or $1\frac{1}{2}$ miles for every ton.

If 600 tons of Coals are sufficient for a given voyage at the rate of 11½ knots per hour, at what rate must the vessel steam to make 500 tons last the voyage?

$$
\begin{array}{llllll}
\text{As } \cancel{600} & : \cancel{500} & :: & 11\cdot5 & : & 10\cdot49 \text{ knots.—Answer.} \\
\quad 6 & \quad 5 & & 11\cdot5 & & \\
\hline
 & & & 575 & & \\
 & & & 1265 & & \\
\hline
 & & & 132\cdot25 & & \\
 & & & 5 & & \\
\hline
 & & & 6)661\cdot25 & & \\
\end{array}
$$

$$
\begin{array}{r|l}
1 & 110\cdot2083(10\cdot49 \text{ knots.—Answer.} \\
1 & 1 \\
\hline
204 & 1020 \\
4 & 816 \\
\hline
2089 & 20483 \\
 & 18801 \\
\hline
\end{array}
$$

If 300 tons of Coals are sufficient for a voyage of 2,000 miles, at the rate of 10 knots per hour, what quantity of coals will be consumed by the same vessel, on a voyage of 3,000 knots, at a reduced speed of 8½ knots per hour?

The consumption of fuel during two or more voyages of known lengths, will vary in the proportion of the square of the velocity, multiplied by the distance traversed.

$$
\begin{array}{llllll}
 & 2 & & 2 & & \\
\text{As } \cancel{2000} : & 10 : & \cancel{300} :: & \tfrac{1}{2})8\tfrac{1}{2} : & \cancel{3000} : & 325\cdot125 \text{ tons.—} \\
\quad 2 & 10 & 3 & 8\tfrac{1}{2} & 3 & [\text{Answer.} \\
\hline
 & \cancel{100} & & 68 & & \\
 & 1 & & 4\tfrac{1}{4} & & \\
\end{array}
$$

[OVER.]

$$\begin{array}{r} 72\frac{1}{4} \\ 3 \\ \hline 216\frac{3}{4} \\ 3 \\ \hline 2)650\frac{1}{4} \\ \hline 325{\cdot}125 \end{array}$$
tons.—Answer.

If 72 Horse Power give a speed to a ship of 6 knots per hour, what Horse Power will be required, to increase the speed to 12 knots per hour.

As $\overset{3}{6} : 1\overset{3}{2} :: \cancel{72} : 576$ horse power.—Answer.

$$\begin{array}{rrr} 6 & 12 & 1 \\ \hline 36 & 144 & \\ 6 & 12 & \\ \hline \cancel{216} & 1728 & \\ 3 & 1 & \\ \hline & 3)1728 & \\ \hline & 576 & \end{array}$$
horse power.

HORSE POWER AND CONSUMPTION OF FUEL, WITH AN INCREASE OF SPEED.

If 50 tons of Coals per day give a speed to a vessel at the rate of 10 miles per hour, what increase of speed should there be with the consumption of 100 tons per day ?

As $\underset{1}{\cancel{50}} : \underset{2}{\cancel{100}} :: 10^{3} : 12{\cdot}6$ knots, nearly.—[Answer.

		10
		10
		100
		10
		2
		1000
1 × 1 =	1	2000(12·6
		1
1 × 3 = 3 × 1 = 300		1000
32 × 2	64	
2 × 2 = 4	364	728
36 × 12 =	43200	272000
366 × 6	2196	
	45396	272376

If a small vessel with 9 Horse Power has a speed of 3 miles per hour, how many Horse Power will it require, to increase the speed to 6 knots per hour ?

As $3^{3} : 6^{3} : \underset{1}{\cancel{9}} : 72$ horse power.—Answer.

3	6

$$
\begin{array}{rr}
9 & 36 \\
3 & 6 \\
\hline
\cancel{27} & 216 \\
3 & 1 \\
\hline
 & 3)216 \\
\hline
 & 72
\end{array}
$$

If 20 lbs. of Coals are required for a speed of 3 miles per hour, what increase of speed should there be with a connsumption of 160 lbs. per hour?

$$
\begin{array}{l}
\qquad\qquad\qquad\; 3 \\
\text{As } \underset{1}{\cancel{20}} : \underset{8}{\cancel{160}} :: \underset{3}{3} : 6 \text{ miles per hour.—Answer.}
\end{array}
$$

$$
\begin{array}{r}
3 \\
\hline
9 \\
3 \\
\hline
27 \\
8 \\
\hline
6 \times 6 = 36)216(6 \\
216
\end{array}
$$

HOW TO FIND THE SIDE OF A RIGHT ANGLE TRIANGLE.

A Right Angle Triangle whose sides are 21-feet and 45·7-feet, find the hypothenues?

Rule.—To find the hypothenues of a Right Angle Triangle when two sides are given: square the two sides and add their product together, then extract the square root of that sum, and the root found will be the Answer.

$$21 \times 21 = 441\cdot$$
$$45{\cdot}7 \times 45{\cdot}7 = 2088{\cdot}49$$

```
    5 | 2529·49(50·29-feet.—Answer.
    5 | 25
  --- | ----
 1002 |   2949
    2 |   2004
 ---- | ------
10049 |   94500
      |   90441
      |   -----
```

Find the hypothenues of a Right Angle Triangle, the one side is 36-feet, the other 34·7-feet?

$$36 \times 36 = 1296$$
$$34{\cdot}7 \times 34{\cdot}7 = 1204{\cdot}09$$

```
    5 | 2500·09(50·
    5 | 25
  --- | ----
  100 | ··00
```

Find the side of a Right Angle Triangle, the hypothenues is 50-feet, and the other side is 34·7-feet?

$$50 \times 50 = 2500$$

$$34{\cdot}7 \times 34{\cdot}7 = 1204$$

$$\begin{array}{r|l} \text{Then } 2500 - 1204 = 3 & 1296(36\text{-feet.—Answer.} \\ 3 & 9 \\ \hline 66 & 396 \\ & 396 \end{array}$$

To find the third side of a Right Angle Triangle, when the hypothenues and one side is given.

Rule.—Add the hypothenues and one side together, and multiply that sum by their difference, and the square root of the product will be equal to the third side. This must be evident, as the sum of any two quantities multiplied by their difference, is equal to the difference of their squares.

Then as above $50 + 34{\cdot}7 = 84{\cdot}7 \times 15{\cdot}3 = \sqrt{1295{\cdot}91} = 36$,
$50 - 34{\cdot}7 = 15{\cdot}3$ [nearly.

HOW TO FIND THE PITCH OF A SCREW PROPELLER.

First.—Find the diameter by measuring the length of the blade or fan to the centre of screw shaft, also find the circumference from the diameter.

Second.—Stretch a line from midship centre of rudder post, to centre of stern post, fore and aft, if any means is at hand to look this line out of winding with the screw shaft do so.

Third. -Bring the after edge of the fan close up to this line, and measure how far the forward edge of the fan is from this line, which will be a part of the circumference, say 2-feet 6-inches.

Fourth.—Place a square with the stock, parellel to this line, and the blade of the square touching the edge of the fan.

Fifth.—Measure from where the fan touches the line, to the edge of the blade of the square, in a fore and aft position, say 1-foot.

Then say by proprotion, as 2-feet 6-inches a part of the circumference is to the whole circumference, so is 1-foot a part of the pitch to the whole pitch.

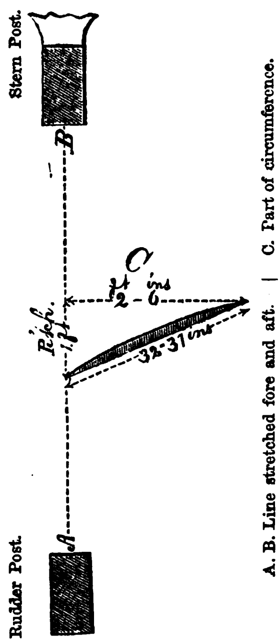
Assuming the diameter to be 16-feet, then it would be

$16 \times 3{\cdot}1416 = 50{\cdot}2656$-feet circumference.

$$\begin{array}{r} 16 \\ \hline 188496 \\ 31416 \\ \hline 50{\cdot}2656 \end{array}$$

[OVER.]

	feet	feet		feet	
Then as	$2\frac{1}{2}$:	50·2656	: :	1 :	20·10624-feet pitch.
	2	2		2	
	5	)100·5312		2	
		20·10624			



It may not be always convenient to find a square to work by, then measure with a foot rule from the forward edge of the fan to the fore and aft. line, say 2-feet 6-inches, then measure the fan across, say 32·31 - inches, * square both these sums, subtract the lesser from the greater, and extract the square root of the remainder will give the other side, which is a part of the pitch, equal 1-foot.

Then as $2\frac{1}{2}$-feet : 50 2656 : : 1-foot : 20·10624-feet pitch.

* Or add the two sums together and multiply by their difference as under.

30 + 32·31 = 62·31 and 62·31 + 2·31 = 143·9361, say $\sqrt{144}$
32·31 — 30 = 2·31. [= 12-inches = 1-foot.

VIVA VOCE EXAMINATION.

For Certificate of competency for Engineers of the First and Second Class.

As this Examination is very varied, and many of the Questions and Answers generally known by Engineers, still many of them escape the memory, and the memory requires to be refreshed by reading them over. We purpose therefore to give Questions and Answers as the case may be, on a variety of Questions which are, or may be put to those concerned.

EXAMINATION ON THE MARINE BOILER.

Q. What distance should Stays be placed apart from each other?

A. From 16 to 18-inches, Stays are placed fore and aft, thwart Ships, and also in a Vertical Position.

Q. What should be the diameter of these Stays?

A. Stays should be large enough so as to bear a strain equal to six times the pressure on the Boiler.

Q. Would Stays placed 16 to 18-inches be suitable for Boilers carrying high pressed steam?

A. Boilers carrying high pressed steam, should be Stayed in accordance with that pressure; small Stays with an increased number are better than using fewer Stays with a large diameter, for the plate will buckle round the Stay and the frequent bending raises a scale and weakens the plate.

Q. State the Valves on the Boilers and their uses?

A. Boilers are fitted generally with Stop Valves, Safety Valves, Vacuum or Reverse Valves, Kingston Valves, and Feed Valves.

Q. State their uses?

A. The Stop Valve is to shut off a Boiler from the Engine, or from each other as required. The Safety Valve is to relieve the Boiler from undue pressure of Steam, it is self acting, and raises when the steam gets to a certain pressure, and the surplus steam escapes to the atmosphere.

Q. Is each Boiler fitted with a Safety Valve?

A. Their are two Valves for each Boiler, one of these is locked down with lock and key, the key is kept by the Commander of the Ship, the other is in charge of the Engineer.

Q. Does the Safety Valve ever get fast, so as to endanger the Boiler?

A. Yes, the Safety Valve has been known to get fast.

Q. Can you state the causes?

A. If the Safety Valve is fitted with a small spindle that works through a bridge in the centre of valve seating (as is generally,) and this spindle is what is called a fine fit, that part of the spindle that projects below this bridge, gathers a crust of a brownish colour which adheres to the brass, and being a fine fit, there is not room enough for the spindle to pass, and it gets jammed.

Q. What would you do with the Safety Valve jammed and the steam up, having arrived in harbour?

A. I would use the Safety Valve from the other Boiler.

Q. But if there was only One Boiler?

A. I would turn the Engines a head, and then a stern alternatelty, open all the tube doors, start the donkey

engine to pump cold water into the Boilers, open the brines to carry off the surplus water.

Q. But suppose the Screw had fouled with some buoy, as in Malta Harbour, and the Engines could not be moved?

A. I would screw down the tail (or blow valve,) on the condenser, then open the blow through valve, the steam would then pass through the discharge pipe into the sea.

Q. Is there any objection to blowing steam through the Condenser and Air-pump as here stated?

A. The Condenser and Air-pump would get hot, much more so than usual, and it has been known that the Condenser from sudden expansion has been cracked.

Q. What is the use of the Reverse Valve on the Boiler?

A. Should the steam get to a low pressure in the Boiler, and a large quantity of cold water let into it, the steam will fall below the pressure of the atmosphere and a vacuum will be formed, the valves will then open from the pressure of the atmosphere, and admit air into the Boiler and prevent a colapse, that is the pressure of the atmosphere would crush the sides of the boiler together, in the same way that you might crush an egg-shell in your hand.

Q. Why then is high pressed Boilers not fitted with Reverse Valves?

A. High pressed Boilers (or what is the same thing,) Boilers carrying high pressed steam, are generally made Cylindrical, and in this shape strong enough to resist the atmospheric pressure, and such as Locomotive Boilers, where they have flat surfaces, are so Stayed as to be strong enough to resist atmospheric pressure.

Q. What is the use of the Kingston Valve?

A. The Kingston Valve is fitted generally to the bottom of the Ship, so that repairs of blow off pipes,

cocks, &c., may be done without the Ship going into the dry dock, this Valve is also self-acting, and will shut from the pressure of the water on the outside.

Q. Can you give any rule for the use of a Safety Valve, for the given dimentions of a Boiler.

A. Mr. Murray, states in his Treatise on the Marine Engine, that 80 square inches of Bar Grate is allowed for every Horse Power, and that half a square inch of a Safety Valve is required for every Horse Power, which would be $\frac{80}{144}$ equal to $\frac{5}{9}$ of a square foot of Bar Grate, it would follow then that for every $\frac{5}{9}$ of a square foot of Bar Grate, there should be the half of a square inch of Safety Valve.

Q. What is the difference between half an inch square and the half of a square inch?

A. The half of a square inch gives an area of 32 square eight parts, for there are 64 square eight parts in a square inch, and a half inch square gives an area of 16 eight parts, or the fourth of an inch square.

Q. What is the bursting pressure of Cylindrical Boilers?

A. Mr. Fairbarn, shows that the bursting pressure of a Boiler, 3-feet diameter, and made of plate $\frac{1}{4}$ of an inch thick, is 450 lbs. pressure per square inch, and a Boiler 6-feet diameter, and made with plate $\frac{1}{2}$ of an inch thick, is 450 lbs. pressure per square inch, thus showing that the thickness of plate for building Boilers with, should be in proportion to their diameter.

Q. What is the weakest part of a well made Boiler?

A. The riveted joints is the weakest part. Mr. Fairbarn gives the proportions, strength of plate 100, double rivetted 70, and single rivetted 56, also that joints rivetted by machinery, are 14 per cent. stronger, than when done by hand.

Q. How much of the strength of Boiler Plate is lost when red hot?

A. When Boiler Plate gets red hot, it has lost $\frac{5}{6}$ of its strength.

Q. At what temperature will Water get into Globules, when poured upon hot plate?

A. About the temperature of 350°.

Q. At what temperature is Wrought Iron at its strongest?

A. The strength of Wrought Iron increases with its temperature, from 32° of Fahrenheit to 550°, thus showing how much less Iron will carry in frost, than in warm weather.

Q. Will the temperature of Steam be increased by water suddenly thrown on red hot plate?

A. Mr. Fairbarn states in his work of Information for Engineers, that to the extent of an ounce of water suddenly thrown on red hot plate, rose the temperature from 460° to 600°, thus showing that the ordinary safety valve is inadequate for its escape.

Q. At what temperature will Fresh Water boil at?

A. The boiling point of Fresh Water with the barometer at 30° is 212°, but water will boil at various temperatures; as at 28 inches of mercury, water will boil at $208\frac{1}{2}$°, and on the Plains of Quito where the atmospheric pressure is as low as 21 inches of mercury, water will boil at 195°. Water will boil at a very low temperature in a vacuum.

Q. Can you state the boiling point of deep sea water, with the barometer at 30 inches of mercury?

A. The boiling point of deep sea water whose density is $\frac{1}{32}$ of saturation, is 213.2—at $\frac{2}{32}$ it boils at 214.4—at $\frac{3}{32}$ it boils at 215.5—and at $\frac{4}{32}$ it boils at 216.7, and so on

increasing with the density of the water at the rate of about 1.2 in temperature for every additional $\frac{1}{32}$ of density.

Q. At what density is the water in the boilers of sea-going Steamers generally worked at.

A. From $\frac{1}{32}$ and $\frac{3}{4}$ to $\frac{2}{32}$ or $\frac{5}{8}$ of the feed water is blown off in the shape of brine and $\frac{3}{8}$ is evaporated.

Q. Will boilers gather scale at this density, say $\frac{2}{32}$?

A. Yes.

Q. How is this Scale taken off the boilers?

A. With a variety of tools made for the purpose of iron and faced with steel.

Q. What is the composition of this Scale?

A. Dr. Ure's analysis of Sea Water, is, that of 1000 parts, 34 of these are solid matter, 25 parts of the 34 are chloride of sodium (or common salt) 5.3 the sulphate of magnesia, 3.5 chloride of magnesium, 0.2 carbonates of lime and magnesia, and 0.1 the sulphate of lime. The salt is held in solution and blown off. The scale is composed of the 9.1 remaining parts.

Q. At what density is the water in the boiler when the salt begins to gather into a solid?

A. The greatest saturation or density is $\frac{12}{32}$ or $\frac{3}{8}$ of the whole quantity is solid matter held in solution, beyond this point of saturation the salt begins to settle at the bottom of the boiler, and will accumulate while the water is evaporated, until the salt reaches the furnace, and the boiler is burned.

Q. What quantity of heat is lost in blowing off half the quantity of feed water supplied to the boiler.

A. The feed water at the temperature of 100° enters, the boiler, and the half of this water is blown off at 214.4 is as follows.

$$\frac{214\cdot4-100}{990+214\cdot4-100}=10\cdot36 \text{ per cent.}$$

```
214·4              214·4
100                100
-----              -----
114·4 + 990 = 1104·4)114·40(0·1036 nearly.
                   11044
                   -----
                    39600
                    33132
                    -----
                     6468
```

Q. Is the scale a bad conductor of heat that adheres to the boiler?

A. Yes, William Nystran, of Philadelphia, tells us in his work, that iron is 30 times a better conductor of heat than saturated scale, that adheres to boilers using deep sea water. Also, that when all the heating surface is covered with this scale to the thickness of $\frac{5}{16}$ of an inch, that 44 per cent. of the heat is lost and goes up the chimney.

Q. What is the composition of fresh water?

A. Fresh water is a composition of hydrogen and oxygen gas.

Q. What are their proportions?

A. The proportion of hydrogen to oxygen by weight, are as 1 of hydrogen is to 8 of oxygen, and by measure, there are 2 measures of hydrogen for 1 of oxygen.

Q. What will decompose water into these two gases?

A. Galvanism applied by a battery.

Q. Can these two gases hydrogen and oxygen again produce water?

A. Yes, two French chemists, to verify this experiment, made an immense reservoir of oxygen and another of hydrogen gas, and caused a small stream from each to

meet and inflame, and so to continue for several days, the result was a large quantity of excellent water, (Jamieson's Mechanical Dictionary.) The Engineer may find in every day practice, where he is using a lighted candle, that if the flame of the candle comes in contact with cold iron, that the gas from the candle will condense and produce water, and much to his annoyance, gather into drops and fall on the wick of the candle, and extinguish his light.

Q. What is latent heat?

A. Latent heat, is heat that disappears in bodies, such as ice or steam, and is not sensible to the thermometer. According to the experiments of Raguult, the total heat estimated from the freezing point in steam at the boiling point, are 1146·6 Fahrenheit; the sensible heat in steam at boiling point is 212°, minus 32° freezing point=180, therefore 114·6·6 minus 180° equal 966·6°, the latent heat is steam. Latent heat in ice, a pound of ice or snow at 32° temperature, mixed with a pound of water at 172° temperature, will just be melted, and the temperature will be 32°, showing that the melting of ice or snow from a temperature of 32° to water of the same temperature will absorb 140° of heat in its liquidation.

Q. What is called Joule's "equivalent" of work done by heat?

A. Joule's equivalent is the heat that will raise one pound of water, one degree will raise a weight of one pound 772-feet high. (Information for Engineers.)

Q. With what rapidity will heat import itself to a colder body?

A. Heat will import itself to a colder body, as the square of the difference of the temperature between the two bodies.

Q. Can you explain the cause of the boiler wasting away in the steam chest?

A. There is much difficulty in arriving at a clear answer to this question, it is said by some that it is the latent heat, but we have seen a superheater that had been in use for more than four years, and the iron did not show the least signs of wasting away, we think it arises from the plates getting wet and drying when the steam is down, and gathering a scale of rust with the action of the atmosphere. That part of the boiler covered with water is protected by a scale that adheres close to the iron, this protects the plate from the action of the sea water or atmospheric air.

STRENGTH OF MATERIAL, (*Stretching Strain.*)

Q. What is the average strain a bar of iron 1-inch square will carry?

A. The average strain of good iron may be taken at 25 tons per square inch.

Q. Will a bar of iron be weakened after it is stretched until it is broken?

A. No, some experiments made at Woolwich on the strain of bar iron, show that after the bar was broken from strain, that a piece of the same bar when tried again sustained more strain than it did before, it was tried several times, and it was found it took more to break it each time, (there is a limit to this,) but its last strain was 32 tons.

Q. Will plate iron stand an equal strain with bar iron?

A. No, Mr. Fairbarn showed by experiments made on boiler plate, that 23 tons was the strain for every square inch of section, either with or across the fibre for the best sorts of iron.

CRUSHING FORCE OF IRON.

Q. What is the crushing force of wrought iron ?

A. The crushing force of wrought iron may be taken at the half of its stretching strain, say 12 tons.

Q. What is the stretching strain of cast iron per square inch ?

A. Cast iron is of great variety in quality, but the average may be taken at 6 to 7 tons per square inch of section.

Q. What is its crushing force ?

A. Cast iron will bear a crushing force equal to seven or eight times its stretching strain, or equal to 50 tons crushing force per square inch of section.

Q. Can you state the relative strength of beams ?

A. According to the principles of Galileo, the strength of beams are inversely as to their length, directly as to their breadth and the square of their depth, that is to say that a beam of 10-feet between its supports will carry 20 tons, let the supports be placed 5-feet apart only, and the same beam will carry 40 tons, if the beam is increased double its breath it will carry double the weight, and if double the depth it will carry four times the weight.

STRENGTH OF COLUMNS.

Q. What are the strength of columns ?

A. We learn from Mr. Hodgkinson, of Manchester, that if a cast iron column exceed in length 30 times its diameter, it will give way by bending, but if its length is less, it will give way partly by bending and partly by crushing.

Q. Does this apply to columns, or shores of wood ?

A. No, a column of wood should not exceed its diameter seven times.

Q. Can you give any rule for the strength of shafting?

A. The strength of shafts are in proportion to the cubes of their diameter.

Q. What strain or twist will a wrought iron shaft of a given diameter bear?

A. The rule is to multiply the power in pounds by the length of the shaft in feet, and by the leverage in feet, divide this product by 55 times the number of degrees in twist, (a degree is the $\frac{1}{360}$ part of a circle,) and the fourth root of the quotient, will be the diameter of the shaft in inches.—*From Mr. Brunton's Work on Mechanics, Glasgow.*

Q. What is meant by multiply by the power in pounds?

A. If we say the pressure on the piston is 40 tons, then this would be the power, (but it would require to be reduced to pounds,) and the length of the crank would be the leverage.

Q. Will wrought iron shafts after working for years, show fracture, which were apparently sound before?

A. Yes.

Q. What is the likeliest part of shafts to show fracture?

A. The journals are generally smallest in diameter, therefore less able to bear the strain.

Q. Can you give any reason why iron shafts that have been working for years apparently sound, should afterwards show signs of weakness?

A. The frequent jerking with a heavy strain, destroys the inertia of a portion of the shaft slowly, and for some time imperceptable on the same principle that a cast iron beam will not bear 900 compressions from a cam without breaking, although the force applied by the cam is not more than one half of the load, the beam will carry the breaking strain of this beam.–From *Mr. Bourne's Catechism.*

Q. What is a vacuum ?

A. Vacuum is an empty space.

Q. Can a vacuum be produced without an air-pump ?

A. An air-pump will not extract all the air out of a vessel, although it will make a good vacuum.

Q. Generally speaking, are there good vacuums and bad vacuums ?

A. Yes.

Q. Can a vacuum be formed without an air-pump ?

A. Yes, blow steam into a vessel such as a condenser, where a valve is attached that opens outwards, the steam will force any water, air, or other gases out and supply their place; the condenser being full, shut the valve for the admission of steam, and admit a jet of cold water which will condense the steam, and a vacuum is formed.

Q. You say there are good and bad vccuums. how are these tested ?

A. By a barometer and the pressure of the atmosphere.

Q. What is a barometer ?

A. There are two kinds of barometers, one to test the vacuum formed in the condenser of steam engine, the other the pressure of the atmosphere, the principle of both are the same.

Q. How does the atmosphere act on a barometer ?

A. The barometer fitted to the steam engine has a small glass tube at least 30-inches long, and placed in a vertical position, the lower end is placed in an open cup containing mercury, to the top end a pipe is fitted air-tight and lead into the condenser, when a vacuum is formed the atmospere presses on the mercury in the open cup and forces the mercury up the glass tube in proportion to the weight of the atmosphere and the vacuum formed.

The thermometer is an instrument for measuring the temperature, it is a fine glass with a large hollow ball at the bottom, and is filled half way up the tube with mercury, it is made hot until the mercury rises to the top, and it is sealed over by fusing this glass tube with the blow pipe, this excludes the air, and the cooling of the mercury leaves a vacuum in its descent, and stops at a point denoting its temperature. The thermometer is connected with the barometer because the expansion or contraction from heat or cold the mercury will rise or fall; one degree of heat will expand mercury $\frac{1}{9600}$ part of its bulk, therefore the mercury will rise or fall in the barometer according to temperature, although the pressure of the atmosphere is not altered.

Q. Can you describe the weather barometer as it is sometimes called?

A. This is also a glass tube close at one end, inserted into an open cup filled with mercury, the mercury is run into the tube until it is full; the open end may be stopped with the finger, the tube inverted and immersed in the cup, the finger removed, the mercury will descend equal to the pressure of the atmosphere.

Q. Are there any other kind of gauges besides a mercury gauge?

A. Yes, the burbon gauge, which is in general use

Q. When the barometer shows 25-inches as the vacuum in the condenser, while the pressure of the atmosphere is equal to 30, what is it that remains in the condenser equal to the other 5-inches of mercury?

A. Air and watery vapour.

Q. How does air get into the condenser?

A. From any leakage about the cylinder or condenser;

there is also a small portion of air mixed with the injection water.

Q. How is it that there is watery vapour?

A. The water gets heated from the condensation of steam, and produces this vapour.

Q. How is the height of the water in the boilers known?

A. By gauge cocks and gauge glasses.

Q. Are these liable to get deranged and lead to accident?

A. Yes.

Q. From what cause will the gauge glass get deranged?

A. The passages are liable to get choked from the scale in the boiler, or from the boiler being fed with muddy water, while the ship is steaming in a dirty river, such as the river Hooghly.

Q. Can you give a description of the action of the water in the gauge glass, under these circumstances?

A. The gauge glass being fixed to the boiler so as to show the water at what is called half glass, when the water is at its proper working level; if the lower communication gets choked or partially so, the water will show lower in the glass (with little or no motion) than in the boiler, and if the passage is not cleared, the water may keep rising until it shows itself by falling down from the top of the glass, or should the top communication get choked and the bottom one clear, then the water will rise in the glass until it reaches the top, although the water in the boiler is as low as the bottom of the glass.

Q. Can you show how it is known when the gauge glass is in good working order with the steam up?

A. When the steam is up, and the gauge glass is in good working order with the water in the glass so as to be easily seen, the water will have a motion up and down in the

glass, from half an inch to an inch, although the ship may be laying in harbour without the slightest motion, and while at sea, the motion of the water in the glass will be guided less or more by the motion of the ship; but should the water appear stationary or without motion in the gauge glass, then something is wrong with the passages, either they are choked from dirt, or the small cocks are left shut while it was intended they should be left open: under these circumstances, the gauge cocks should be tried at once, to find out the level of the water, and the communication cocks on the gauge glass should be frequently opened, so as to blow out the mud that had gathered in the passage. Should the water rise so high in the glass as to be out of sight, a doubt should be raised on the mind of the Engineer of the watch, whether the top communication or passage to the glass was not closed, either by the cock that closes this passage being left shut, or from some other cause, then the gauge cocks should be tried at once, and no water blown off until this was known. Accidents of a serious nature have arisen from the top passage being choked, and the pressure in the boiler forcing the water to the top of the glass, while the water was low in the boiler; an Engineer in charge of boilers under these circumstances, should be on his guard.

SUPER-HEATED STEAM.

Q. What is super-heated steam?

A. It is steam that has received an addition of heat from metal or matter of some kind, and contains more heat than is due to its pressure.

Q. What is meant by "than is due to its pressure?"

A. The heat in steam varies with its pressure at 15 lbs.

pressure, the heat is 250°, but steam at this pressure is super-heated, and in use daily at a temperature of 300° and upwards.

Q. What is the advantage to be derived from super-heated steam?

A. When steam is super-heated, its quantity is increased from the watery vapour it contains, a small portion of its latent heat becomes sensible. When this steam is used expansively, it carries its pressure longer because it has more heat, which prevents its pressure from falling so fast from condensation in the cylinder; also the heat by which the steam is super-heated had reached the bottom of the chimney, and would have passed off to the atmosphere.

Q. Does this super-heated steam require more injection water?

A. No, as part of the latent heat has become sensible and the steam drier.

Q. Why does a jet of high pressed steam issuing suddenly into the atmosphere not burn the hand?

A. It is a law in all matter compressible whether they are solids or fluids, that when compressed they evolve heat, and when suddenly released from that compression by a small jet into the atmosphere, they have a great affinity for heat. This explains why a thermometer suspended under the receiver of an air-pump, has its temperature lowered some degrees under exhaustion; and the converse why air suddenly compressed to one fifth of its volume, will light tinder or other inflamable matter. Also in solids, the effect of compression in reducing capacity for heat is very remarkable, a piece of soft iron at the temperature of the atmosphere, when quickly hammered, its capacity for heat is reduced, and it gives heat to a blue

red.—*(Mechanics Magazine.)* Before the invention of the lucifer match, Smiths frequently lighted their fires from the hammering of a piece of soft iron, but the same piece of hammered iron would not do a second time, as it would split up into pieces.

SURFACE CONDENSATION.

Q. What is meant by surface condensation?

A. It is a cooling surface used for the condensation of steam, so that the steam so condensed can be used as fresh water, without being mixed with any other liquid.

Q. Can you explain the surface condenser as applied to the steam engine?

A. The surface condenser as it is called, is a cylinder filled with tubes, about $\frac{5}{8}$ of an inch in diameter, with space left round each tube; some of these condensers are fitted for the steam to be condensed inside the tubes, and the cooling water outside, and others the reverse

Q. Is this surface condenser the same in principle, if not in form, as was patented by Samuel Hall, Esq., Basford, about 30 years ago, and was applied to the British Queen steam ship, built on the Clyde; also the steam ship Megaera, fitted by Messrs. Sewards and Co., of London?

A. Yes, an account of them is to be found in the *Mechanics Magazine.*

Q. What is the advantage gained by the use of this condenser?

A. The fresh water being returned to the boiler, was to supersede the necessity of using scum or brine pipes, also to save the heat carried off with the brine, equal to ten per cent, and also to save the labour of scaling boilers.

Q. Has these advantages been realized?

A. In practice many disadvantages has arisen.

Q. State what you recollect of them ?

A. It has been found necessary in many cases to put on scum pipes, and use them as before, to prevent priming, also the water acts with injurious effect on the plate of the boiler.

INJECTION WATER.

Q. With what velocity will injection water enter the condenser of a steam engine, the orifice is 8-feet below the level of the water alongside, and suppose the vacuum to be equal to 15 lbs. pressure ?

A. The velocity will vary as the square root of the head of the water, multiplied by 8·1, thus 15 lbs. are equal to 34-feet high ; therefore 34 plus 8=42-feet, and the square root of 42 are 6·48, this multiplied by 8·1 × 6·48 =52·48-feet per second.

Q. What are the cubical contents of a condenser, taking the cubical contents of the cylinder at 1 ?

A. The condenser should be half of cylinder, the air-pump from a sixth to an eighth, the discharge valve one fourth the area of air-pump, and discharge pipo one seventh the area of air-pump.

ATMOSPHERIC AIR.

Q. What is the composition of atmospheric air ?

A. Of 100 parts by measure, 79 parts are nitrogen and 21 oxygen. There are also other two substances contained in the atmosphere, near to the earth's surface carbonic acid, which is about $\frac{1}{2500}$ of the whole, the other watery vapour, which varies with climate, it is seldom less than $\frac{1}{200}$, or more than $\frac{1}{60}$ of the bulk of the air.—*Johnstone's Chemistry of Common Life.*

COMPOSITION OF COALS.

Q. What is the composition of coal?

A. The composition of coal varies with the different kinds, therefore the variety is very great. A tabular analysis of coals, is to be found in *Mr. Murray's Work on the Marine Engine.*

Mr. Predaux says, that coals may be taken at 80 per cent. carbon and 5 hydrogen, the anthrocite is 91 per cent. carbon, and from ·3 to 4 hydrogen; the Welsh contains less oxygen than the Lancashire, Newcastle, Scotch, or Foreign coals, therefore these require a stronger draught.

Q. What quantity of atmospheric air, does it require to produce the greatest amount of heat from 1 lb of coal?

A. Much will depend on the quality of coal. *Mr. Templeton* tell us, from 120 to 180 cubic feet of atmospheric air is required for 1 lb. of coal. *Mr. Murray*, from 150 to 300 cubic feet, the former quantity being sufficient chemically; but as a quantity of the atmosphere passes up the chimney unconsumed, the latter quantity is required.

Q. Would it be beneficial for those, whose duty it is to use coals for raising steam, to have a description of the kinds of coals supplied?

A. Yes, the quality of coals could be described on the coal receipt, with their chemical composition.

Q. Will nitrogen gas combine with carbon, and support combustion?

A. No, it is the oxygen of the atmosphere only, which by measure is very little more than one fifth of the whole.

Q. Does the admission of air at the back of the furnace, or through the furnace door, burn the smoke, increase the heat in the furnace and save fuel?

A. It will help to consume smoke, but we have never

known it to save fuel: we believe that the proper place for admitting air into the furnace, is through the furnace bars, this keeps the bars from burning, and the air gets heated and mixed with the carbon suitable for combustion.

WATER IN THE CYLINDER.

Q. Is the cylinder bottom or lid liable to be broken by water, or any solid substance getting between these and the piston, while the engines are in motion and not room enough to pass?

A. Yes, this might take place with a single engine, but when two engines are working at right angles to each other on one shaft; the one that is near the end of the stroke has so little leverage to resist the other engine at half stroke, that something must give way.

Q. Would not the relief valves on the cylinders, save from accident by the discharge of the water?

A. It does so sometimes, but not always.

Q. How is it that these relief valves allow water to escape and not steam?

A. There is a spiral spring strong enough to resist the pressure from the steam, but yields to the pressure from water as the force is greater.

THE EXPANSION VALVE.

Q. What is the use of the expansion valve?

A. This valve is used for shutting off the steam from the cylinder, at various portions of the stroke of the engine, so as to give the greatest power with the smallest quantity of steam.

Q. Can you explain how this takes place?

A. If a cylinder is filled with steam at 20 lbs. pressure,

to one fourth of the stroke of the piston, then at half stroke the pressure would be 10 lbs., and at the end of the stroke 5 lbs. Now if the cylinder was filled with steam at 5 lbs. pressure the whole length of the stroke, there would be as much steam used at the 5 lbs. pressure as was used at the 20 lbs., while the power of the one to the other would be as 2·4 is to 1.

Q. What is the use of the snifting valve?

A. This valve is to admit air between the discharge valve and the air-pump bucket on the return stroke, allows the bucket to return easier, and on the bucket lifting the water any irregularity in the speed of the engine, the air will compress according to circumstances.

Q. What is the use of the blow through valve?

A. This valve has a communication with the slide jacket and the condenser, the valve is shut from the pressure of steam, (in many cases it is not used,) but when used it opens this communication between the slide jacket and condenser; the pressure of steam forces the water or air out of the condenser at the blow valve, and when the steam comes rushing out at the blow valve, this shows the condenser is filled with steam; a little injection water will produce a vacuum, and the engine will start with less pressure of steam.

Q. What is the use of the bilge injection valve?

A. The bilge injection valve is used when a greater quantity of water gets into the bilge, then the bilge pumps can keep under, or should anything choke the sea injection, the water could be let into the bilge, and injection water used in this way until the other was cleared.

Q. Should this valve be tried occasionally and the ends of the pipe frequently cleaned, so that if an accident happened, the valve would be in good order?

A. Yes, according to the adage, prepare for difficulties, and you will not have them.

Q. If one engine broke down, what would you do ?

A. I would disconnect the broken-down engine, namely, the cylinder, air-pump, and eccentric connecting rods, place the slide valve in the middle of its travel, set it tight up to the face of cylinder, take off the relief valve on top and bottom of cylinder, to prevent a vacuum being formed.

Q. Then in starting with one engine, what centre is the easiest to cross ?

A. The easiest centre to cross, is when the throw of the crank or crank pin is between the centre of crank shaft and the connecting rod.

Q. A tube of 4-inches diameter is re-placed by 4 small tubes of the same total area, what is the heating surface of the 4-inch tube, compared with the 4 small tubes ?

A. The area of a tube 4-inches diameter is $4 \times 4 = 16$-inches area, 4 tubes at 2-inches diameter are $2 \times 2 = 4$ area of 1 tube, and $4 \times 4 = 16$-inches area, then $2 \times 3{\cdot}1416 = 6{\cdot}2832$-inches the circumference of 1 tube, and $6{\cdot}2832 \times 4 = 25{\cdot}1328$ and $4 \times 3{\cdot}1416 = 12{\cdot}5664$ circumference of large tube of 4-inches diameter, therefore $25{\cdot}1328 - 12{\cdot}5664 = 12{\cdot}5664$, thus showing the heating surface of the small tubes to be double that of the large tubes, whose areas are equal.

Q. The safety valve of a boiler is 6-inches diameter, but the heating surface requires one of 10-inches, what is the diameter of the second valve ?

A. The area of 10-inches diameter is $10 \times 10 = 100$-inches circular, and $6 \times 6 = 36$ area of valve on boiler, therefore $100 - 36 = 64$-inches, the area of second valve, and the square root of 64 is 8, the diameter of second valve.

Q. The area of a safety valve is 4-inches, and a second valve

has to be fitted double the diameter of the former, find its area ?

A. The square root of 4 is 2 the diameter of first valve, this doubled is $2+2=4$ the diameter of the second valve, and $4\times4=16$ the area ot second valve, this is evident as areas are proportional to the squares of their diameters.

Q. Can too much air be admitted into the furnace ?

A. Too much air will lower the heat of the furnace and be injurious to combustion, which takes place about 800°.

Q. Why is a good Burbon gauge more correct than the mercury gauge with fixed scale ?

A. The mercury gauge with fixed scale has an error in it, as the surface of the mercury is not stationary, for it falls in the cup as it rises in the tube.

The cushioning of the piston is the eduction port shut by the slide, the vapour left is compressed by the piston moving to the end of the stroke ; this vapour compressed brings the momentum of the piston to rest easily or softly, ready to return without jaring, and has therefore got the name of cushioning.

If orders are given to raise steam as quick as possible and the boilers not run up, run no more water in the boilers than is really necessary : it is evident that a small quantity of water will heat sooner than a large quantity, with the same amount of heat applied, and without heat there is no combustion, it has been already stated in this work, that charcoal begins to burn at 700°, hydrogen at 800°, (that is with a supply of air or oxygen gas.)

The indicator is a small cylinder, nicely fitted with a piston, it represents the atmospheric engines as it is called, getting the steam on the underside only, and acting against a spring, this spring shows not only the pressure of steam but also the vacuum.

Q. If you found the condenser leaky at sea how was this defect to be remedied.

A. If it was at a convenient part it might be patched.

Q. Where do the condensers begin to decay.

A. Those that are so formed so that a large portion of them lies in the bilge of the Ship begin to decay in the bottom.

Q. How would you remedy a leak in the bottom.

A. Run water in the bilge so as to cover the leak, or if it rose higher so that it was not convenient to run the water so high, then box in the condenser with wood and lead a pipe to carry water inside this box.

Q. What pressure or force does it require to punch a hole in a plate of iron $\frac{3}{8}$ of an inch thick and $\frac{3}{4}$ of an inch in diameter.

A. We learn from John W. Nystrom, C.E. Philadelphia, that from 20 to 24 tons are required per square inch of section, that is taking the circumference of the hole with the thickness of the plate; the force requisite for one sixteenth is 660 lbs. and $660 \times 12 \times 6 = 47520$ lbs. or 21·21 tons, and adds that it takes the same force for shearing as for punching, but much will depend on the punch or shears being sharp.

HOT BEARINGS.

A Bearing will be found to work for days together without getting hot, and afterwards get hot, and those attending to them at their duty without being able to give a satisfactory reason why. The heat in the working parts of the machinery are generally tested by the hand; sometimes other duties call the attention of the Engineer of the watch away from the bearings, and the smell of the burning tallow or oil, will call his attention.

If the bearing is very hot, slow the engines, slack back the nuts or keys, as the case may be, and apply the water sparingly at first, so as not to hurt the metal from sudden contraction of the heated part where the water is applied, and when the bearing has cooled down sufficient that the heat in it will not burn tallow, then use a mixture of oil and tallow, with a quantity of sulphur or French chalk, and when it is cooled down to near the heat of the hand, tighten the bearing up again until it shows a little to the slack side, for if the least increase of temperature takes place, and not room left for expansion from heat, the friction will again increase, and the bearing get hot as before.

Friction does not increase with the velocity, but as each revolution has the same friction where the pressure per square inch is the same; and if 20 revolutions are made instead of 10, then the pressure will be double in point of time, and if 10 revolutions per minute, heat a bearing to 100°, but get no warmer from radiation. It is reasonable therefore to expect that 20 revolutions per minute, would

increase the heat of the bearing as it would double the friction with only the same time for radiation, and if an increase of heat, there would be an increasd expansion in the bearing, and if the bearing had little or no room left after the heat was 100° for expansion, the bearing would get nipped or too tight, and a hot bearing would soon follow.

Since the adoption of the screw as a propeller, the increase of speed in the working parts of the machinery has been necessary, and the bearings getting hot occasionally. The application of salt water to keep the bearings cool, is a necessary evil, because their is a certain amount of galvanic action going on, where brass, iron, and salt water are in contact, or where wrought iron, cast iron, and salt water are together, unless the surface is protected by some coating, but it is not always easy to apply this to rubbing surfaces.

INFLAMABLE SUBSTANCES.

Coals ignited from spontaneous combustion on board ship, must always be a very serious matter, and on board a steam ship every attention should be paid to see that coals are stowed away dry, but where circumstances do not admit of this from wet weather and the coals exposed, then an enquiry should be made into the nature of the coals, whether they are hard, and has very little affinity for oxygen in the particles, or coals that are easy broken, and has a great affinity for oxygen. A Thermometer

should be placed in the shoot from the deck, and the temperature noted. Great care should be taken to see that open lids are placed on these shoots, and on no account to bring a light to the shoot, until there has been means used for the escape of any gas that has gathered in the bunker.

Companies or private individuals supplying coals could always have in the coal receipt, the kind of coals and the analysis of them.

Of substances called combustable, and thus called because they combine with oxygen so inergetically as to become luminous ; there are only a few that will begin to burn at the ordinary temperature of the atmosphere. The metalic basis of potash, called potassium, inflames immediately on being brought in contact with the coldest ice, and continues to burn while the metal lasts; so great is its affinity for oxygen, that it seizes upon it from water at all temperatures.

To Inflame sodium, the metalic basis of soda by contact with water, a temperature of 80° is sufficient, phosphorus begins to burn at 120°, sulphur at 300°, charcoal at 700°, hydrogen at 800°.

A piece of phoshorus exposed to the air, at the temperature of 50° or 60°, burns slowly indeed; a few sticks of phosphorus when laid together and allowed to oxydise, they will warm each other so as to melt and burn into flame.

The oils and tallows mixed with cotton waste, and a large surface exposed to the air, combine so rapidly with oxygen to form a sort of resin, that by the heat evolved, the mass will be set on fire, and hence the origin of spontaneous fires, so called, which consumed the Naval Arsenal of St. Petersburgh, and in many cases the Cotton Mills of England.—*Mechanics Magazine.*

FEEDING BOILERS.

A sufficient and regular supply of water into the Boilers should always be, with the Engineer of the watch, one of his most important duties, for should the iron become red hot it looses $\frac{5}{8}$ of its strength, and explosion can scarcely be avoided. This may cause the loss of the ship, if not the loss of all hands.

Boilers are fitted with gauge cocks and gauge glasses, and when the glass is in good working order every confidance can be placed in it, to show the height of the water in the boiler. When the steam is up, there will be a motion of the water in the glass from half inch to an inch, if the glass is in good working order, although the ship may be shored up in the dry dock. Should the water appear stationary in the glass, then it is out of order, and should be attended to at once. There are means to be used for clearing the gauge glass, which every Engineer attending upon boilers should be acquainted with before being entrusted with this charge.

Should the boilers prime much, if this arises from dirty water, a little grease forced into the boilers with a syringe made for the purpose will help to settle the water, but should priming be an every day occurance from the boilers being too small, then a steam chest, or small pipes fitted round inside of the boilers, so as to gather the steam regular over the surface of the water with holes in the top side of these pipes; but should these means fail to stop priming, the sooner these boilers are taken out and replaced by larger ones, the more profitable it will be for the proprietors, for there is not only a loss of fuel by the water leaving the boiler with the steam, but also a loss of power, besides the water destroys the engines.

BURSTING PRESSURE OF BOILERS.

The following Table shows the bursting pressure equivalent to the ultimate strength of the riveted joint, as deduced from experiments made by William Fairbarn. Esq., Manchester, and published in a valuable work titled Information for Engineers.

The boilers are cylindrical from 3 to 8 feet diameter, showing the thickness of metal in each plate respectively, at a pressure of 450 lbs. per square inch.

Diameter of Boilers.		Cylinder Boilers, bursting pressure of the riveted joint 34,000 lbs. to the square inch	Thickness of Plates in decimal parts of an inch.
feet.	inches.		
3	0		·250
3	6		·291
4	0		·333
4	6		·376
5	0		·416
5	6	·450 lbs.	·458
6	0		·500
6	6		·541
7	0		·583
7	6		·625
8	0		·666

The above table shews that the thickness of the plate for building cylinder boilers with, should be in proportion to their diameter. The crushing strain of cylinder flues are inversely as their diameter, that is, a flue 1 foot diameter will bear double the strain of a flue 2 feet diameter ; also if the strength of the plate is represented by 100, the double riveted joint would be 70, and the single riveted joint 56.

QUESTIONS FOR PRACTICE.

What is the weight of a connecting rod, the strap weighs 10 cwt, the crosstail is as heavy as the strap and half of the body of the rod, and the body of the rod is as heavy as the strap and crosstail added together?

Let the body of the rod be equal to x, the crosstail equal to $\frac{1}{2}x$ plus 10 cwt., and the strap is equal to 10 cwt.

Therefore $x = \frac{1}{2}x + 10 + 10$ cwt.

$$\begin{array}{l} \qquad\qquad\qquad 2 \\ \hline 2x = x + 20 + 20 \\ \ x \quad\ x \\ \hline x = - \ 20 + 20 = 40 \text{ cwt.} \end{array}$$

Therefore the body of the rod	=	40 cwt.
The crosstail $= \frac{1}{2}x + 10$	=	30 cwt.
And the strap	=	10 cwt.

$$\begin{array}{r} 20)\overline{80} \\ \hline 4 \text{ tons —Ans} \end{array}$$

Or by single position.

The body of the rod is half of the weight, let it be represented by 4

The strap and crosstail = 4, total = 8

Then the body of the rod =	4
Crosstail equal half of the body rod = 2+1 =	3
The strap equal =	1
	8

Then by proportion as 1 : 10 : : 8

$$\begin{array}{r} 8 \\ \hline 20)\overline{80} \\ \hline 4 \text{ tons.} \end{array}$$

What is the length of a piston rod, one third of its length is in the cylinder, one fourth in the cylinder cover, and 3-feet above the cover ?

Let p be equal to the length of the rod.

Therefore $p=\frac{1}{3}p\ \frac{1}{4}p+$ 3-feet.
12

12 $p=4\,p\ 3\,p+36$.
Or 12 $p=7\,p\ +36$
7 7

And 5 $p=$ — 36, or 5 times the length of the rod.

And $36\div5=7\frac{1}{5}$ the length of the rod.

The reason why this is multiplied by 12, is that 12 is the common denominator of $\frac{1}{3}$ and $\frac{1}{4}$.

Or by vulgar fractions.

$\frac{1}{3}+\frac{1}{4}=\frac{3}{12}+\frac{4}{12}=\frac{7}{12}$.

The addition of $\frac{1}{3}+\frac{1}{4}$ shows that $\frac{12}{12}$ is the length of the rod, therefore $\frac{12}{12}-\frac{7}{12}=\frac{5}{12}$, this $\frac{5}{12}$ is represented by 3-feet above the cover.

Therefore as 5 : 3 : : 12-feet : $7\frac{1}{5}$-feet.—Answer.

$$\begin{array}{r} 12 \\ \hline 5)36 \\ \hline 7\frac{1}{5} \end{array}$$

To find the weight of a cast iron ball, cube the diameter, take an eighth of the product and an eighth of that again, add the two together for the weight in lbs. avoirdupois.—*Hutton's Mathematics.*

What is the weight of a cast iron ball, 6-inches diameter?

Or $\frac{6 \times 6 \times 6}{7} = 30{\cdot}857$ lbs.

```
   6
   6
  ——
  36
   6
  ——
7)216
 ————
 30·857
```

```
   6
   6
  ——
  36
   6
 ———
8)216
 ——
 8)27
   3·375
  ————— [Ans.
 30·375 lbs.—
```

$$\frac{6 \times 6 \times 6}{8} = 27 + \tfrac{1}{8} = 30{\cdot}275 \text{ lbs.—Answer.}$$

PITCH OF THE SCREW PROPELLER.

What must be the pitch of a screw, to propel a ship at the rate of 12 knots per hour, the engines are direct action, and the crank shaft makes 60 revolutions per minute, allowing 25 per cent for slip?

For all questions of this kind the following rule is applicable:—

Rule.—Multiply the pitch of the screw without the slip by 100, and divide that product by 100, minus the per cent, for slip, will give the pitch required.

$$\frac{12 \times 6080}{60 \times 60} = 20{\cdot}266 \text{ pitch without slip.}$$

$$\frac{100}{100-25} = \frac{100}{75} = \frac{4 \times 20{\cdot}266}{3 \times} = 27{\cdot}021 \text{ feet. pitch required.—[Answer.}$$

$$\begin{array}{r} 6080 \\ 12 \\ \hline 60)72960 \\ \hline 60)1216 \\ \hline 20{\cdot}266 \text{ pitch without slip.} \end{array} \qquad \begin{array}{r} \text{feet.} \\ 20{\cdot}266 \\ 4 \\ \hline 3)81{\cdot}064 \\ \hline 27{\cdot}021 \text{ pitch.—Answer.} \end{array}$$

To find proof, deduct 25 per cent. from 27·021 feet. = 20·266 feet.

$$\frac{25}{100} = \frac{1 \times 27{\cdot}021 \text{ feet.}}{4} = 20{\cdot}266 \text{ feet.}$$

$$\begin{array}{r} \tfrac{1}{4})27{\cdot}021 \\ 6{\cdot}755 \\ \hline 20{\cdot}266 \text{-feet proof.} \end{array}$$

What must be the pitch of a screw, to propel a ship at the rate of 11 knots per hour, the crank shaft makes 30 revolutions per minute, and the multiple of the screw gear is 2 to 1, allowing 15 per cent. slip ?

$$\frac{11 \times 6080}{30 \times 2 \times 60} = 18{\cdot}577\text{-feet pitch without slip.}$$

$$\frac{100}{100-15} = \frac{100 \times 18577}{85} = 21{\cdot}856 \text{ feet. pitch required.—Answer.}$$

$$\begin{array}{r} 6080 \\ 11 \\ \hline 30 \times 2 = 60)66880 \\ \hline 60)1114{\cdot}66 \\ \hline 18{\cdot}577 \end{array} \qquad \begin{array}{r} \div \tfrac{100}{85} = \tfrac{20}{17} \times 18{\cdot}57\dot{7} \\ 20 \\ \hline 17)371{\cdot}55\dot{5} \\ \hline 21{\cdot}856\text{-feet pitch} \\ \text{[required.—Ans.} \end{array}$$

What is the weight of a cast iron ball, 6-inches diameter?

Or $\frac{6 \times 6 \times 6}{7} = 30{\cdot}857$ lbs.

$$\begin{array}{r} 6 \\ 6 \\ \hline 36 \\ 6 \\ \hline 7)216 \\ \hline 30{\cdot}857 \end{array} \qquad \begin{array}{r} 6 \\ 6 \\ \hline 36 \\ 6 \\ \hline 8)216 \\ \hline 8)27 \\ 3{\cdot}375 \\ \hline 30{\cdot}375 \text{ lbs.—} \end{array} \text{ [Ans.}$$

$$\frac{6 \times 6 \times 6}{8} = 27 + \tfrac{1}{8} = 30{\cdot}275 \text{ lbs.—Answer.}$$

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To find proof, deduct 15 per cent. from 21·856-feet.

$$\frac{15}{100} = \frac{3 \times 21{\cdot}856}{20} = 3{\cdot}279\text{-feet.}$$

And $21{\cdot}856 - 3{\cdot}279 = 18{\cdot}577$, proof.

What is the slip per cent. of a screw 20-feet pitch, worked by gearing 2 to 1, engines making 39976 revolution per day, the distance run by ship being 250 knots?

$$\frac{39976 \times 2 \times 20}{60 \times 80} = 263 \text{ miles by screw.}$$

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263 :  100 : : 13
        13
       ----
263)1300(4·94
    1052
    ----
     2480
     2367
     ----
      1130
      1052
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Rule.—As the speed of screw is to 100, so is the difference between the speed of screw and ship to slip per cent.

MISCELLANEOUS TABLE.

Cast Iron varies much, but a cubic foot of cast iron may be taken at 4 cwt.

A cubic foot of Fresh Water weighs $62\frac{1}{2}$ lbs.

Ditto of Salt Water weighs 64 lbs.

Ditto of Oil weighs 58 lbs.

6·23 gallons one cubic foot.

A cubic foot of Atmospheric Air weighs ·076 lbs., equal to $1\frac{2}{9}$ oz.

Ditto of maleable Iron weighs 4 cwt., 1 qr., or 477·8 lbs.

Ditto of Tin weighs 464 lbs.

Ditto of Lead weighs 6 cwt., 1 qr., 8 lbs., or 707·81 lbs.

Tin fuses at the temperature of 442° of Fahrenheit.

Lead fuses at the temperature of 612° of „

A cubic foot of Copper weighs 5 cwt.

$32\frac{1}{2}$ cubic feet of Steam at Atmospheric pressure weighs 1 lb.

One cubic foot is equal to 1728 cubic inches.

Twenty seven cubic feet 1 cubic yard.

One square foot is equal to 144 square inches.

277·274 cubic inches in one gallon.

A circular inch is to a square inch, as 7854 is to 10,000, or $\frac{7854}{10000}$ of 1.

A Nautical Mile is equal to 6082·66-feet, but in practice it is used at 6080-feet.

An English Mile is equal to 1760 yards, or 5280-feet.

Air heated 1° degree, its bulk will be increased about $\frac{1}{435}$ part.

Water heated 1° degree, its bulk will be increased about $\frac{1}{6666}$ part.

Mercury heated 1° degree, its bulk will be increased about $\frac{1}{9800}$ part.

Hutton's Mathematics.

The Latent Heat in Steam at atmospheric pressure is 966·6

2240 lbs. one Ton and 2240÷62·5=35·84 cubic feet of Fresh Water 1 ton.

2240÷64=35 cubic feet of deep Sea Water 1 ton.

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